RETScreen® International
Clean Energy Decision Support Centre
www.retscreen.net

RETScreen® Software
Online User Manual

Solar Air Heating Project Model

Natural Resources Canada
Ressources naturelles Canada

Canada

Background

This document allows for a printed version of the RETScreen® Software Online User Manual, which is an integral part of the RETScreen Software. The online user manual is a Help file within the software. The user automatically downloads the online user manual Help file while downloading the RETScreen Software.

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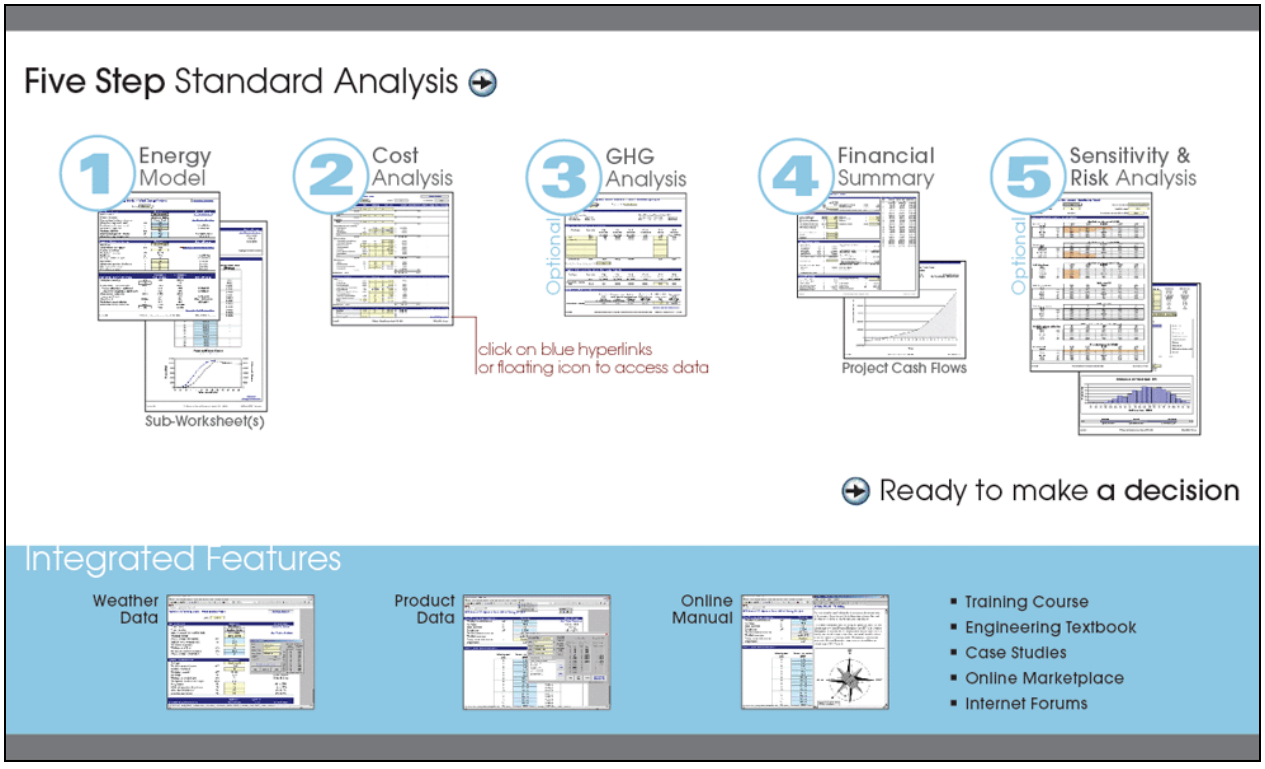
Brief Description and Model Flow Chart

RETScreen® International is a clean energy awareness, decision-support and capacity building tool. The core of the tool consists of a standardised and integrated clean energy project analysis software that can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies (RETs). Each RETScreen technology model (e.g. Solar Air Heating Project, etc.) is developed within an individual Microsoft® Excel spreadsheet "Workbook" file. The Workbook file is in-turn composed of a series of worksheets. These worksheets have a common look and follow a standard approach for all RETScreen models. In addition to the software, the tool includes: product, weather and cost databases; an online manual; a Website; an engineering textbook; project case studies; and a training course.

Model Flow Chart

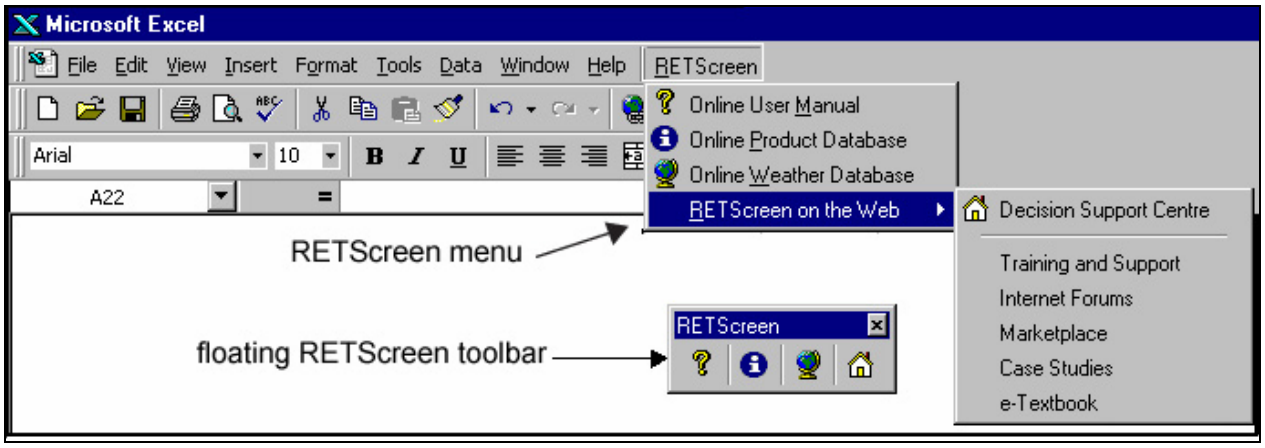
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets. The RETScreen Model Flow Chart is presented below.



RETScreen Model Flow Chart

Data & Help Access

The RETScreen Online User Manual, Product Database and Weather Database can be accessed through the Excel menu bar under the "RETScreen" option, as shown in the next figure. The icons displayed under the RETScreen menu bar are displayed in the floating RETScreen toolbar. Hence the user may also access the online user manual, product database and weather database by clicking on the respective icon in the floating RETScreen toolbar. For example, to access the online user manual the user clicks on the "?" icon.

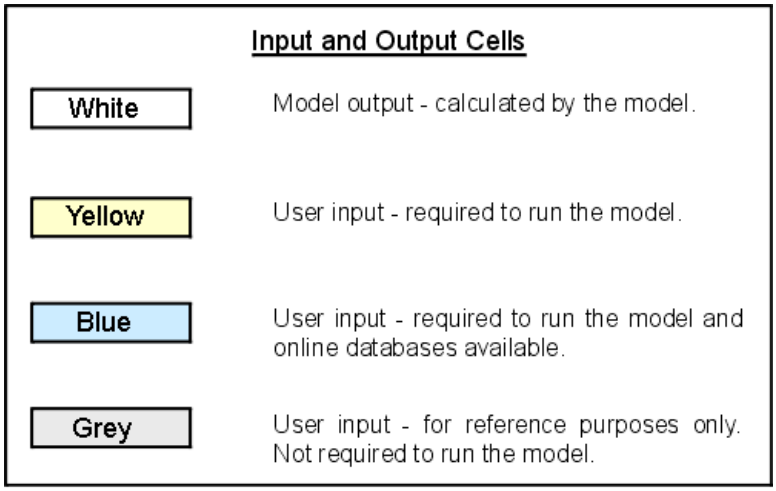


RETScreen Menu and Toolbar

The RETScreen Online User Manual, or help feature, is "cursor location sensitive" and therefore gives the help information related to the cell where the cursor is located.

Cell Colour Coding

The user enters data into "shaded" worksheet cells. All other cells that do not require input data are protected to prevent the user from mistakenly deleting a formula or reference cell. The RETScreen Cell Colour Coding chart for input and output cells is presented below.


Input and Output Cells
White
Model output - calculated by the model.
Yellow
User input - required to run the model.
Blue
User input - required to run the model and online databases available.
Grey
User input - for reference purposes only. Not required to run the model.

RETScreen Cell Colour Coding

Currency Options

To perform a RETScreen project analysis, the user may select a currency of their choice from the "Currency" cell in the *Cost Analysis* worksheet.

The user selects the currency in which the monetary data of the project will be reported. For example, if the user selects "$," all monetary related items are expressed in $.

Selecting "User-defined" allows the user to specify the currency manually by entering a name or symbol in the additional input cell that appears adjacent to the currency switch cell. The currency may be expressed using a maximum of three characters ($US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. $ reduced by a factor of a thousand, hence k$ 1,000 instead of $ 1,000,000).

If "None" is selected, all monetary data are expressed without units. Hence, where monetary data is used together with other units (e.g. $/kWh) the currency code is replaced with a hyphen (-/kWh).

The user may also select a country to obtain the International Standard Organisation (ISO) three-letter country currency code. For example, if Afghanistan is selected from the currency switch drop-down list, all project monetary data are expressed in AFA. The first two letters of the country currency code refer to the name of the country (AF for Afghanistan), and the third letter to the name of the currency (A for Afghani).

For information purposes, the user may want to assign a portion of a project cost item in a second currency, to account for those costs that must be paid for in a currency other than the currency in which the project costs are reported. To assign a cost item in a second currency, the user must select the option "Second currency" from the "Cost references" drop-down list cell.

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can increase the zoom to see

Name of unit	Symbol for unit
ampere	A
calorie	cal
cubic feet per minute	cfm
day	d
degree Celsius	°C
degree Fahrenheit	°F
dollar	$
feet	ft
gallon[1]	gal
hectare	ha
hertz	Hz
horse-power	hp
hour	h
joule	J
kilogram	kg
kilometre	km
kilowatt	kW
litre	L
megawatt	MW
metre	m
mile	mi
mile per hour	mph
million Btu	mmBtu
pascal	Pa
percentage	%
person day	p-d
person hour	p-h
person trip	p-trip
person year	p-year
pound	lb
pound-force/square inch	psi
second	s
tonne[2]	t
volt	V
watt	W
week	w
yard	yd
year	yr

Name of Prefix	Symbol for Prefix
kilo	k
mega	M
giga	G

List of Units, Symbols and Prefixes

those symbols correctly. Usually, symbols will be fully visible on printing even if not fully appearing on the screen display.

Units, Symbols & Prefixes

The previous table presents a list of units, symbols and prefixes that are used in the RETScreen model.

Note: 1. The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon.

2. The tonne (t) unit used in RETScreen refers to metric tonnes.

Unit Options

To perform a RETScreen project analysis, the user must choose between "Metric" units or "Imperial" units from the "Units" drop-down list.

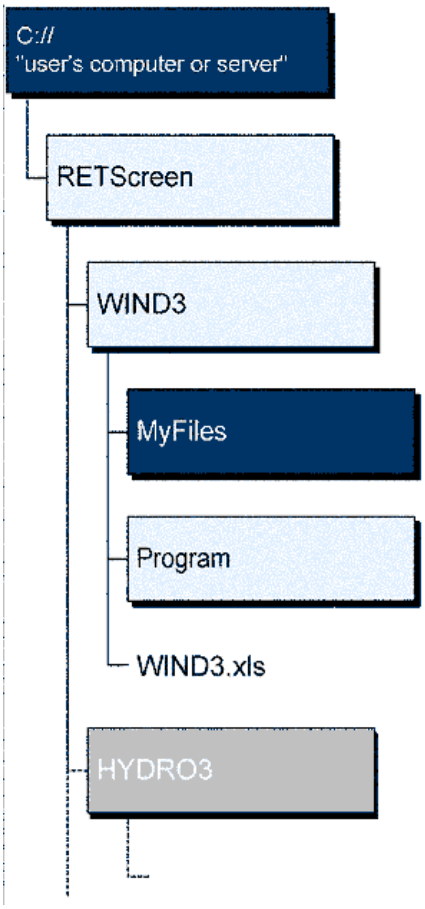
If the user selects "Metric," all input and output values will be expressed in metric units. But if the user selects "Imperial," input and output values will be expressed in imperial units where applicable.

Note that if the user switches between "Metric" and "Imperial," input values will not be automatically converted into the equivalent selected units. The user must ensure that values entered in input cells are expressed in the units shown.

Saving a File

To save a RETScreen Workbook file, standard Excel saving procedures should be used. The original Excel Workbook file for each RETScreen model can not be saved under its original distribution name. This is done so that the user does not save-over the "master" file. Instead, the user should use the "File, Save As" option. The user can then save the file on a hard drive, diskette, CD, etc. However, it is recommended to save the files in the "MyFiles" directory automatically set by the RETScreen installer program on the hard drive.

The download procedure is presented in the following figure. The user may also visit the RETScreen Website at www.retscreen.net for more information on the download procedure. It is important to note that the user should not change directory names or the file organisation



RETScreen Download Procedure

automatically set by RETScreen installer program. Also, the main RETScreen program file and the other files in the "Program" directory should not be moved. Otherwise, the user may not be able to access the RETScreen Online User Manual or the RETScreen Weather and Product Databases.

Printing a File

To print a RETScreen Workbook file, standard Excel printing procedures should be used. The workbooks have been formatted for printing the worksheets on standard "letter size" paper with a print quality of 600 dpi. If the printer being used has a different dpi rating then the user must change the print quality dpi rating by selecting "File, Page Setup, Page and Print Quality" and then selecting the proper dpi rating for the printer. Otherwise the user may experience quality problems with the printed worksheets.

Solar Air Heating Project Model

The RETScreen® International Solar Air Heating Project Model can be used world-wide to easily evaluate the energy production (or savings), life-cycle costs and greenhouse gas emissions reduction for two basic applications: ventilation air heating and process air heating. The model is designed specifically for the analysis of transpired-plate solar collectors. This emerging technology has been successfully applied in a range of applications from small residential to larger commercial/industrial scale ventilation systems, as well in the air drying processes for various crops.

Six worksheets (*Energy Model, Solar Resource, Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis), Financial Summary* and *Sensitivity and Risk Analysis (Sensitivity)*) are provided in the Solar Air Heating Project Workbook file.

The *Energy Model* and *Solar Resource* worksheets are completed first. The *Cost Analysis* worksheet should then be completed, followed by the *Financial Summary* worksheet. The *GHG Analysis* and *Sensitivity* worksheets are optional analyses. The *GHG Analysis* worksheet is provided to help the user estimate the greenhouse gas (GHG) mitigation potential of the proposed project. The *Sensitivity* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. In general, the user works from top-down for each of the worksheets. This process can be repeated several times in order to help optimise the design of the solar air heating project from an energy use and cost standpoint.

In addition to the worksheets that are required to run the model, the *Introduction* worksheet and *Blank Worksheets (3)*are included in the Solar Air Heating Project Workbook file. The *Introduction* worksheet provides the user with a quick overview of the model. *Blank Worksheets (3)* are provided to allow the user to prepare a customised RETScreen project analysis. For example, the worksheets can be used to enter more details about the project, to prepare graphs and to perform a more detailed sensitivity analysis.

Energy Model

As part of the RETScreen Clean Energy Project Analysis Software, the *Energy Model* and *Solar Resource* worksheets are used to calculate the annual energy production for a solar air heating project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies.

Units

To perform a RETScreen project analysis, the user must choose between "Metric" units or "Imperial" units from the "Units" drop-down list.

If the user selects "Metric," all input and output values will be expressed in metric units. But if the user selects "Imperial," input and output values will be expressed in imperial units where applicable.

Note that if the user switches between "Metric" and "Imperial," input values will not be automatically converted into the equivalent selected units. The user must ensure that values entered in input cells are expressed in the units shown.

Site Conditions

The site conditions associated with estimating the annual energy production of a solar air heating project are detailed below.

Project name

The user-defined project name is given for reference purposes only.

For more information on how to use the RETScreen Online User Manual, Product Database and Weather Database, see Data & Help Access.

Project location

The user-defined project location is given for reference purposes only.

Nearest location for weather data

The user enters the weather station location for reference puproses only in the *Solar Resource* worksheet and it is copied automatically to the *Energy Model* worksheet.

Note: At this point the user should complete the *Solar Resource* worksheet.

Annual solar radiation (tilted surface)

The model calculates the total annual solar radiation incident on the solar collector from monthly data entered by the user in the *Solar Resource* worksheet.

Annual average temperature

The model calculates the annual average temperature from monthly data entered by the user in the *Solar Resource* worksheet.

The annual average temperature typically ranges from -20 to 30°C, depending upon the location.

Annual average wind speed

The model calculates the annual average wind speed from monthly data entered by the user in the *Solar Resource* worksheet.

System Characteristics

The system characteristics associated with estimating the annual energy production of a solar air heating project are detailed below. The system characteristics section are divided into four sub-sections: Base Case Heating System, Building/Process, Airflow Requirements and Solar Collector.

Heating application type

The user selects the heating application type from the two options in the drop-down list: "Ventilation air" and "Process air." "Ventilation air" implies that the system is to be used for heating or pre-heating ventilation air in a building. "Process air" implies that an industrial or agricultural process is involved where warm or hot air is required. The worksheet will be adapted according to the selection made by the user.

Building/Process

This sub-section contains information that describes some of the physical aspects of the building/process related to the solar air heating system.

Building/Process type

The user selects the type of building or process from the drop-down list.

When the application is for "Ventilation air," there are three options from the drop-down list: "Industrial," "Commercial" and "Residential." The model uses the same procedure for commercial and residential buildings, but uses a different procedure for industrial buildings. If an

industrial building is selected, additional information is required so that destratification savings can be calculated.

When the application is for "Process air," there are three options from the drop-down list: "Crop drying," "Combustion air" and "Other." The model considers each process type in the same way since these applications have little impact on the physical design or operation of the system. These are usually the simplest installations and do not interact with the building heating or ventilation loads.

For commercial and residential systems, the solar air heating system supplies a constant flow of outdoor air preheating the ventilation air. On cold days, the solar collectors preheat the air and a heater in the air-handling unit provides the necessary remaining heat.

The operation of an industrial system is significantly different than commercial and residential systems. Industrial systems do not use an auxiliary heater in the air handler; a makeup air heating system provides the additional heat required. On cold days, the solar collector alone might not be able to deliver the minimum specified air temperature. Therefore, to temper the air, solar heated air is mixed with some warm recirculated air to raise the delivered air temperature to the Minimum delivered air temperature specified by the user.

Indoor temperature

The user enters the indoor temperature of the building. For most buildings this is the thermostat setpoint for room temperature, typically 21°C or 70°F.

In the case of process air heaters, the space behind the collector (whether the collector is mounted on the wall or the roof) may be the space where the process heat is utilised. In this case, the user enters the average temperature at which the process occurs.

The indoor temperature typically ranges from 20 to 40°C for residential and commercial ventilation air systems and for process air systems. For industrial ventilation air systems, it typically ranges from 20 to 25°C.

Minimum delivered air temperature

The user enters the minimum delivered air temperature for the solar air heating system in an industrial building. This is the temperature at which the air is delivered to the building from the ventilation system. It is usually less than room temperature.

On cold days when the solar collector alone cannot achieve this temperature, the system further raises the incoming air temperature by mixing some warm recirculated air drawn from near the ceiling. The mixing is controlled by motorized dampers actuated by temperature sensors. Introducing recirculated air into the ventilation flow has the effect of reducing the flow rate through the solar collector. But this lower flow rate allows the collector to provide a larger temperature increase. A balance is achieved between these two effects to arrive at a constant

delivered air temperature. The minimum delivered air temperature typically ranges from 5 to 21°C.

Maximum delivered air temperature

The user enters the maximum delivered air temperature for the solar air heating system. The maximum temperature is the temperature at which no additional heat is required by either the process or the ventilation system. In a ventilation system, this temperature may correspond to the building's balance point temperature. In a crop drying process, this temperature may correspond to the temperature at which the product is in danger of scorching. The maximum delivered air temperature typically ranges from 10 to 60°C for residential and commercial ventilation air systems and for process air systems. For industrial ventilation air systems, it typically ranges from the minimum delivered air temperature and 60°C.

Building temperature stratification

The user enters the temperature stratification in the building before installation of the solar air heating system. This value represents the difference between the air temperature measured at ceiling level and the air temperature measured near the floor.

In high-ceiling industrial buildings, there can be a significant temperature gradient between the floor and the ceiling as heat generated within the building naturally rises. This effect, known as stratification, can result in increased heat loss through the roof and through rooftop exhaust vents.

A ventilation system can reduce this effect by delivering relatively cool ventilation air at ceiling level, promoting mixing of indoor air. In doing so, the ceiling air temperature is reduced and the building temperature becomes more uniform, thus less stratified.

Stratification temperature can be measured directly in an existing building. Buildings with low ceilings, and low internal gains (e.g. warehouses) will have modest stratification (1 to 5 ºC). Buildings with high ceilings and high internal gains (e.g. manufacturing facilities) may have significant stratification (5 to 15 ºC).

Floor area served by solar collector

The user enters the floor area (and therefore also the ceiling area) that is ventilated by the solar air heating system. This entry is used to calculate the reduction in ceiling heat loss due to destratification. Typically each square metre of solar collector can serve 7 to 15 m² of floor area.

RSI-value of ceiling/R-value of ceiling

The user enters the thermal resistance of the ceiling in the area served by the solar air heating system. The RSI-value should include the resistance of inside and outside film coefficients and thermal bridging effects of metal framing.

The RSI-value of the ceiling can be calculated using the methods contained in the ASHRAE Handbook of Fundamentals. In most cases, it is probably sufficient to enter the RSI-value of the insulation. Typical ceiling RSI-values range from 0.1 to 10 m²-ºC/W, and generally have somewhat (50%) more insulation than the walls.

RSI-value of building wall or ceiling/R-value of building wall or ceiling

The user enters the thermal resistance of the building wall or ceiling to be covered by the solar air heating system collector. In the case of process air heaters, the collector may be mounted on a sloped roof. It could also be remotely mounted (e.g. on a false wall with no heat behind). The RSI-value should include the resistance of inside and outside film coefficients and thermal bridging effects of wood or metal framing.

The RSI-value of the wall can be calculated using the methods contained in the ASHRAE Handbook of Fundamentals. It is sufficient to enter the RSI-value of the insulation for wood-frame walls. Steel-frame walls should use a value of 50% of the insulation RSI-value. Uninsulated block walls have an RSI-value of approximately 0.1 m²-ºC/W. At the other end of this range, the thermal resistance of a super-insulated wall system would be about 10 m²-ºC/W. In the case of a remotely mounted process air system, the user can enter a very high RSI-value to neglect the effect of building heat loss recaptured.

Base Case Heating System

This sub-section contains information that describes the energy system displaced by the installation of the solar air heating system.

Heating fuel type

The user selects the type of heating energy displaced by the solar air heating system. This entry will be used to calculate annual heating energy savings in the *Financial Summary* worksheet. A list of common heating fuel types is provided in the drop-down list. The table below provides the heating value for various fuel types.

Heating Energy Avoided	Fuel Heating Value
Natural gas	37.2 MJ/m³ (10.33 kWh/m³)
Propane	26.6 MJ/L (7.39 kWh/L)
Gasoline	33.7 MJ/L (9.36 kWh/L)
Kerosene	36.6 MJ/L (10.16 kWh/L)
Diesel (#2 oil)	38.7 MJ/L (10.74 kWh/L)
#6 oil	40.5 MJ/L (11.25 kWh/L)
Electricity	1.0 kWh/kWh
Other	1.0

Fuel Heating Value

Note: The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon. "Propane-gal" and "Propane-L" are expressed in terms of liquefied propane.

Heating system seasonal efficiency

The user enters the annual heating system seasonal efficiency (%) (not the instantaneous or peak efficiency). This value should include the effects of cycling and part load performance as well as any loss of heat because of ducting that runs outside of the building envelope. This value is used to estimate the gross energy/fuel requirement to meet the building's heating demand in the base case scenario.

The table below provides typical values of heating system seasonal efficiency. These values should be reduced by 10% if ducting runs outside of the insulated envelope (e.g. in attics).

Heating System Type	Typical Annual Heating System seasonal efficiency (%)
Standard boilers/furnaces (with pilot light)	55 to 65
Mid-efficiency boilers/furnaces (spark ignition)	65 to 75
High-efficiency or condensing boilers/furnaces	75 to 85
Electric resistance	100
Air-source heat pump	130 to 200
Ground-source heat pump	250 to 350

Typical Heating Systems Seasonal Efficiencies

Airflow Requirements

This sub-section contains information that describes the air flow requirements for the application under consideration.

Design airflow rate

The user enters the amount of outdoor air supplied when the system is operating. If it is a building with no existing fresh air ventilation system, either the existing exhaust airflow rate or the new desired ventilation rate may be used.

The amount of outdoor or fresh air brought into the building is usually specified on the building drawings or can be supplied by the building manager. If the ventilation rate is not known, it can be estimated at 36 m^3/h per person for residential and commercial buildings. In an industrial or process application, the airflow requirement will depend on the application involved.

In the case of an industrial system, the air handler will mix solar heated air with recirculated air if the solar heated air's temperature is less than the Minimum delivered air temperature. The minimum delivered air temperature is maintained by reducing the flow of solar heated air. When maintaining the airflow rate at all times is critical and the solar collector is considered to be the only source of ventilation, the design airflow rate can be increased to account for this reduction on cold days. The user can refer to the Average Solar collector flow rate to estimate the design airflow rate increase. Note that increasing the design airflow rate means that during warmer

periods, the system will be overventilating. If an alternate path for ventilation air is available (i.e. infiltration driven by an exhaust fan), then the required airflow rate will always be supplied.

Operating days per week (weekday)

The user enters the number of days per week (d/w) during weekdays (Monday to Friday) that the system is in operation. This value depends on the type of application.

Operating hours per day (weekday)

The user enters the average number of hours per day (h/d) during weekdays (Monday to Friday) that the system is in operation. The number of hours per day that a building ventilation system operates usually depends on the length of time people are in the building. This could range from 5 hours for office spaces to 24 hours for residential buildings.

Hours of operation are assumed to be distributed evenly around solar noon. As most fan operation schedules are nearly symmetrical about solar noon, this is a reasonable assumption.

Operating days per week (weekend)

The user enters the number of days per week (d/w) during the weekend (Saturday and Sunday) that the system is in operation. This value depends on the type of application.

Operating hours per day (weekend)

The user enters the average number of hours per day (h/d) during the weekend (Saturday and Sunday) that the system is in operation. The number of hours per day that a building ventilation system operates usually depends on the length of time people are in the building. This could range from 5 hours for office spaces to 24 hours for residential buildings.

Hours of operation are assumed to be distributed evenly around solar noon. As most fan operation schedules are nearly symmetrical about solar noon, this is a reasonable assumption.

Solar Collector

This sub-section contains information that describes some of the physical aspects of the solar air heating system.

Design objective

The user selects the intended characteristics of the solar air heating system from the three options in the drop-down list: "High temperature rise," "Standard operation" and "High air volume." The model then suggests a solar collector area based on this objective and the intended ventilation airflow. The actual collector flow rate used in the model depends on the collector area entered by the user.

It is possible to design a solar air heating system to obtain maximum air temperature rise by reducing the average airflow rate through the collector. High temperature rise usually comes at the expense of lower solar air heating system efficiency. High temperature rise solar air heating systems are sometimes recommended for ventilating buildings in cold climates where delivered air temperatures might otherwise be too low.

High efficiency can be obtained by increasing the airflow (high air volume) and reducing the temperature rise. For a given airflow rate, high air volume solar air heaters are smaller and thus less costly. They do, however, deliver cooler air in general and thus may rely more on a backup conventional heating system. High air volume systems are appropriate for warmer climates or buildings that can tolerate cool delivered air temperatures.

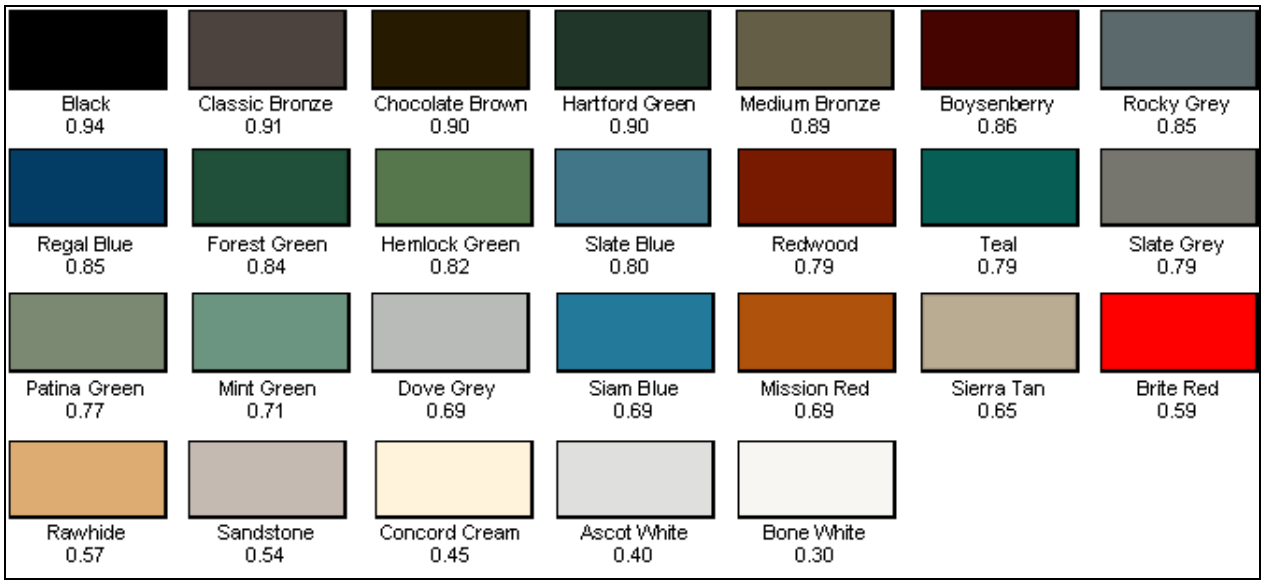
The average SAH fan flow rates per unit area of collector, as used in the model, are given in the table below.

Solar Collector Design Objective	SAH Fan Flow Rate	
	Nominal	Range
High Temperature rise	36 $m^3/h/m^2$	18 to 54 $m^3/h/m^2$
	2 cfm/ft^2	1 to 3 cfm/ft^2
Standard operation	91 $m^3/h/m^2$	54 to 108 $m^3/h/m^2$
	5 cfm/ft^2	3 to 6 cfm/ft^2
High air volume	144 $m^3/h/m^2$	108 to 180 $m^3/h/m^2$
	8 $cfm/h/m^2$	6 to 10 cfm/ft^2

Nominal SAH Fan Flow Rates for Various Design Objectives

Collector colour

The user enters the colour of the solar collector. This entry is for reference purposes only and is not required to run the model. However, there is a relationship between the colour of the solar collector and its performance. Solar absorptivity (a measure of a materials ability to absorb the sun's energy) is related to colour and is entered in the following cell. Black collectors generally have the best performance but other colours are also suitable. The user can consult the RETScreen Online Product Database for more information.



Available Solar Collector Colours

Note: This colour chart is for reference purposes only. Some colours might not appear correctly due to computer monitor variations. For the actual colour chart, please contact the manufacturer.

Solar absorptivity

The user enters the solar absorptivity that corresponds to the colour of the solar collector. Solar absorptivity is a measure of the fraction of incident solar energy that is converted to heat within a material. It is related to colour. Black collector materials generally provide the highest fraction (about 0.94) but other colours are also suitable. The user can consult the RETScreen Online Product Database for more information.

Suggested solar collector area

The model calculates the suggested collector area. This quantity is determined by dividing the design airflow rate by the collector flow rate implied by the chosen design criteria.

In building applications, the area of the solar collector will typically range from 5 m² for single detached houses to the entire sunward facing facade of commercial buildings (excluding doors and windows). As a rough guide, in schools and commercial buildings, there should be a minimum of 1 m² of solar air heating system collector for every 2 persons occupying the building.

Solar collector area

The user enters the area of solar collectors to be installed. North of the equator, the solar collector should be facing the equator, but can be mounted on both south-east and south-west facing walls (and north-east and north-west for project locations South of the equator).

The suggested solar collector area depends on the design airflow rate and design criteria and may differ from the value entered by the user. In general, a higher temperature rise collector will result if the area entered by the user exceeds the suggested solar collector area. Higher efficiency can be achieved by specifying a slightly smaller than suggested collector area.

The user should not enter a solar collector area that differs from the suggested solar collector area by more than 20%.

SAH fan flow rate

The model calculates the fan flow rate for the solar air heating (SAH) system based on the suggested solar collector area and the design objective. This is the total airflow per area of collector that the fan must provide.

This value is provided simply as a reference. If the suggested solar collector area is entered by the user in the "Solar collector area" cell, the SAH fan flow rate will correspond to one of the values in the following table. The collector efficiency is calculated accordingly.

Suggested airflow rates per unit area of collector are shown in the table below.

Solar Collector Design Objective	SAH Fan Flow Rate	
	Nominal	Range
High Temperature rise	36 $m^3/h/m^2$	18 to 54 $m^3/h/m^2$
	2 cfm/ft^2	1 to 3 cfm/ft^2
Standard operation	91 $m^3/h/m^2$	54 to 108 $m^3/h/m^2$
	5 cfm/ft^2	3 to 6 cfm/ft^2
High air volume	144 $m^3/h/m^2$	108 to 180 $m^3/h/m^2$
	8 $cfm/h/m^2$	6 to 10 cfm/ft^2

Nominal Collector Flow Rates for Various Design Conditions

Percent shading during season of use

The user enters the percentage of the solar collector shaded by adjacent buildings or vegetation on a typical operating day. The RETScreen model reduces the available solar radiation by this amount.

The percentage of shading on the wall facing the equator depends on the latitude of the location and the altitude angle the sun must be to clear obstructions to the sunward side of the collector. Approximate values are provided in the table below for various latitudes and altitude angles of adjacent obstructions. If there are no nearby buildings or the altitude angle is less than 10 degrees, a value of zero can be used. If the obstruction does not stretch across the entire horizon the values in the table below should be reduced accordingly.

Latitude	Altitude Angle of Adjacent Buildings or Vegetation (degrees) 10°	15°	20°
< 30	0 %	2 %	5 %
40	2 %	6 %	15 %
50	5 %	12 %	25 %
60 +	8 %	20 %	40 %

Percentage Sun Blockage by Shading Across Entire Horizon

Average solar collector flow rate

The model calculates the annual average flow rate through the solar collector when it is in operation. For commercial and residential buildings, this value is equal to the SAH system fan flow rate and is therefore not shown.

For industrial buildings where some recirculated air may be mixed with the collector air, the average collector flow rate will be lower than the nominal system flow rate. It will likely be approximately 50 to 70% of the SAH fan flow rate in moderate climate. In colder climate, it could be less.

Average air temperature rise

The model calculates the average daytime air temperature rise achieved by the solar air heating system. The actual operating temperature rise will vary considerably throughout the day. It will usually be highest around noon or whenever the solar collector is exposed most directly to sunlight. At the end of the day the temperature rise will be very small.

Incremental fan power

The user enters the increased use of electric power required to operate the makeup air or supply fan of the solar air heating system, in watts per area of solar collector. In a retrofit situation, the solar collector may be connected to an existing outdoor air intake. Depending on the design of the system and the length of connecting duct work, the power required to operate the fan (at the original flow rate), may increase. In new building construction or for retrofits where additional ventilation capacity is required, a fan dedicated to the solar air heating system will be installed. To estimate the added fan operating (electricity) costs, the incremental fan power is required.

A solar air heating system provides a certain amount of buoyancy driven flow, particularly when the collector is tall in aspect ratio. This buoyancy may in fact negate any additional pressure drop on the system in which case no extra fan power is required. If the solar air heating system is well designed (e.g., flow straighteners, rounded transition from the solar collector to the existing system), the increase in fan power may be negligible.

The user is reminded that only **incremental** fan power is considered here. Often the SAH system fan replaces an existing fan. There is only an incremental power use if the replacement is larger than the original or the fan is supplemental to existing capacity.

Attaching solar air heating system collectors to the intake of an existing ventilation air intake could increase fan power by up to 7 W/m² of solar collector. For systems being implemented as part of new construction projects, the solar air heating system should require no more fan power than a conventional system, and therefore the user would enter zero (0).

Annual Energy Production

Items associated with calculating the annual energy production of a solar air heating project are detailed below.

Incremental fan energy

The model calculates the annual increase in electricity (MWh) used to operate the system fan(s) as a result of the addition of the solar air heating system. The incremental fan energy ranges from zero in well designed systems to about 1 or 2% of the solar heat collected. The value is copied automatically to the *Cost Analysis* worksheet.

Specific yield

The model calculates the specific yield of the solar air heating system. This is the annual renewable energy delivered by the solar air heating system divided by the solar collector area. This value represents the entire energy savings provided by the solar air heating system.

Collector efficiency

The model calculates the efficiency (%) of the solar air heating system collector in converting solar radiation into heating of ventilation or process air. The efficiency of the solar air heating system collector is strongly dependent on the design objective. It may vary from less than 40% for a low-flow industrial ventilation system to above 70% for a high-efficiency process air heating system.

Solar availability while operating

The model calculates the percentage of annual solar radiation available to reduce air heating fuel requirements. This value will be less than 100% due to a heating season that is less than a full year, and because of shading, if any occurs.

For locations where heating is required year-round and the system is well located, the solar availability could approach 100%. For warm locations, the solar availability could drop to as low as 60%.

Renewable energy collected

The model calculates the renewable energy collected (i.e. solar heat collected). This is the total amount of solar radiation that is used to heat the air. The amount of solar heat collected will typically range from 0.3 to 0.9 MWh/m² of solar collector.

Building heat loss recaptured

The model calculates the amount of heat that would normally be lost through the building wall that contains the solar air heating system collector, but which is recaptured and transferred back to the ventilation or process air. The reduction in wall heat loss is typically ten times smaller than the solar heat collected or roughly 0.03 to 0.09 MWh/m² of solar collector.

Destratification savings

The model calculates the amount of heat saved due to reduction in ceiling heat loss and destratification of building air, for industrial buildings. Typically, these savings are almost equal to the solar heat collection.

Destratification savings are estimated based on the ventilation system's ability to reduce ceiling air temperature. Monitoring of solar air heating system installations has shown that the system can reduce the ceiling temperature by between 0.5 and 3 ºC.

Renewable energy delivered

The model calculates the renewable energy delivered (i.e. the total annual energy savings of the solar air heating system) due to solar collection, reduced wall heat loss and destratification (where applicable), in MWh. This is also the reduction in space heating load due to the solar air heating system.

The total annual energy savings of the solar air heating system is the sum of the annual solar collected and reduced wall heat loss and typically ranges between 0.4 and 1.0 MWh/m² of collector for commercial and residential buildings. For industrial buildings and processes, the savings could be twice as great where destratification savings are available. This value is copied automatically to the *Financial Summary* worksheet.

Units switch: The user can choose to express the energy in different units by selecting among the proposed set of units: "GWh," "Gcal," "million Btu," "GJ," "therm," "kWh," "hp-h," "MJ." These values are for reference purposes only and are not required to run the model.

Solar Resource

As part of the RETScreen Clean Energy Project Analysis Software, the *Solar Resource* worksheet is used in conjunction with the *Energy Model* worksheet to calculate the annual energy production for a solar air heating system based upon local site conditions and system characteristics. The user should return to the *Energy Model* worksheet after completing this section. The user can consult the RETScreen Online Weather Database for more information.

Site Latitude and Collector Orientation

Site conditions and system characteristics associated with estimating the annual solar energy resource are detailed below.

Nearest location for weather data

The user enters the weather station location with the most representative weather conditions for the project. This information is given for reference purposes only. The user can consult the RETScreen Online Weather Database for more information.

Latitude of project location

The user enters the geographical latitude of the project site location in degrees measured from the equator. Latitudes north of the equator are entered as positive values and latitudes south of the equator are entered as negative values. The user can consult the RETScreen Online Weather Database for more information.

The latitude of the closest weather location can be pasted to the spreadsheet from the online weather database. If the user knows the latitude for the project location, this value should be entered in the spreadsheet by overwriting the pasted value.

Slope of solar collector

The user enters the angle between the solar air heating collector and the horizontal, in degrees. In most building applications, the slope of the collector will be vertical (90º). In process applications such as crop-drying, the collector may be tilted such that it points more directly towards the sun. This angle will correspond roughly to the angle of latitude of the location but can be adjusted by ±15º to optimise seasonal operation.

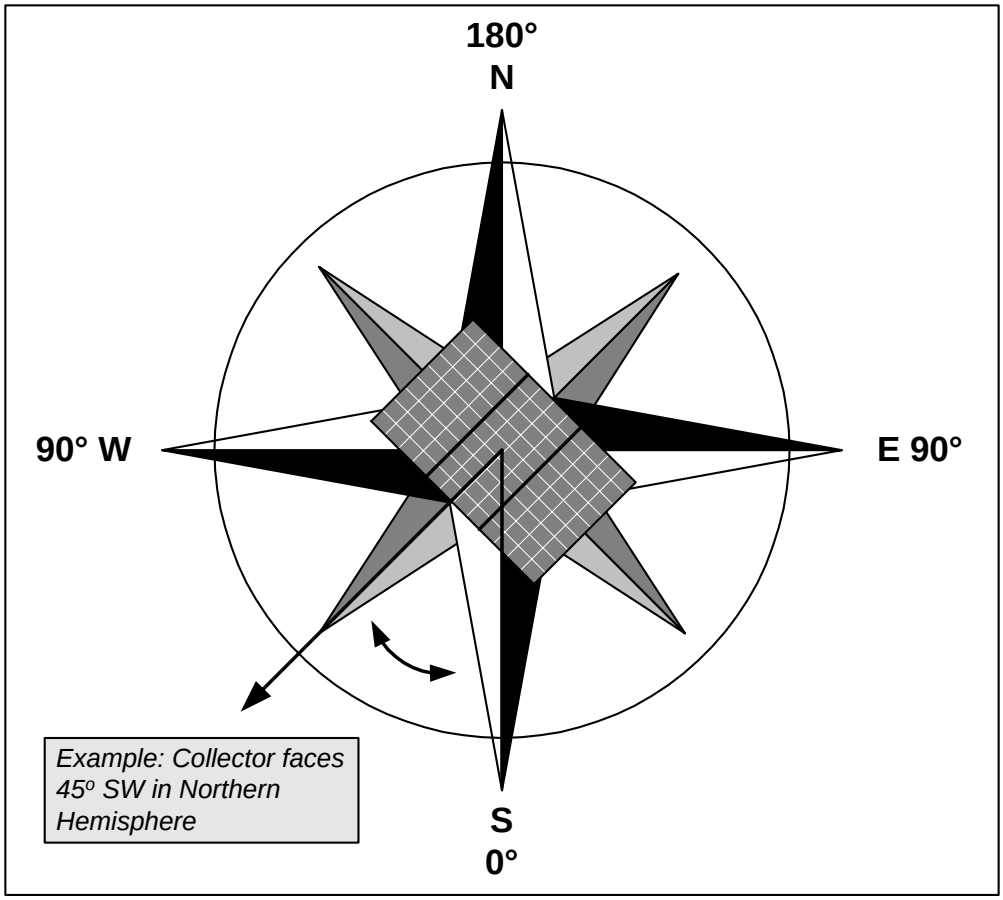
Azimuth of solar collector

The user enters the angle between the projection, on a horizontal plane, of the normal to the surface and the local meridian, with zero due south (for the purpose of this model, the sign has no importance).

The preferred orientation should be facing the equator, in which case the azimuth angle is 0° in the Northern Hemisphere and 180° in the Southern Hemisphere. In the case of a collector mounted directly on the roof of a building, the azimuth is equal to that of the roof, which should be chosen to be as close to equator facing as possible. For example, a solar collector in the Northern Hemisphere facing south-west would have an azimuth angle of 45° (see figure below).

If two walls are being used, the average of the absolute values for the orientation should be calculated. For example, if one wall is 30 degrees west of south (+30°) and the other wall is 60 degrees east of south (-60°), enter 45 degrees. Alternatively, if one wall were due east (-90°), and the other due west (+90°) the average of the absolute values would be 90°.

Note that the azimuth must be entered with respect to true south and not magnetic south. Compasses point to magnetic north (the complement of magnetic south) and azimuth directions based on this measure must be adjusted for the magnetic declination (for more information, refer to "Magnetic declination"). If the azimuth direction is being determined from site drawings, it should be determined what reference the site north is using. Site north does not always correspond to true north, as it is sometimes adjusted for convenience in the site and building drawings.



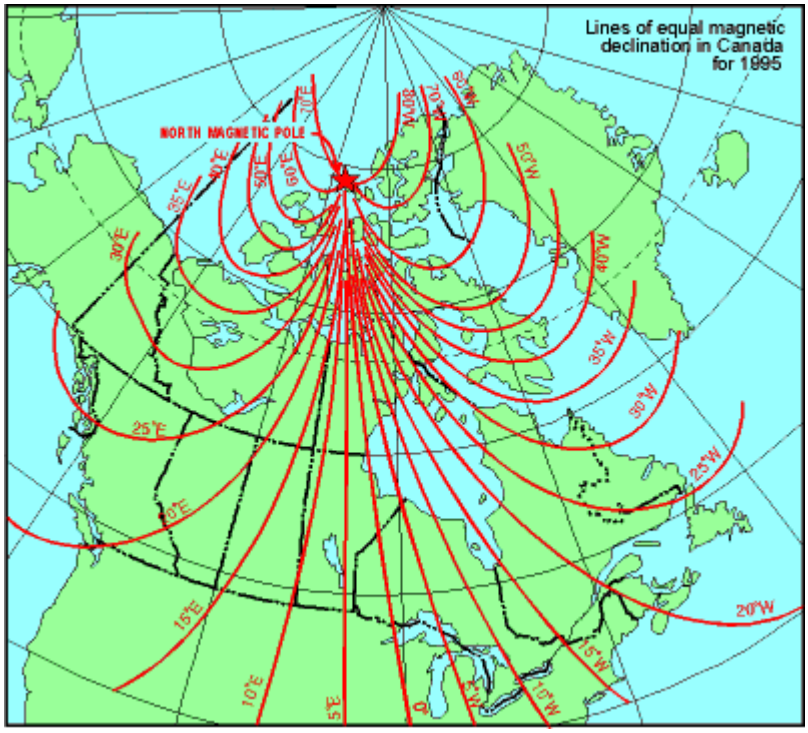
Azimuth of Solar Collector [adapted from Ross, 1999]

Magnetic declination

A magnetic compass does not normally point to true north. In fact, over most of the Earth it points at some angle east or west of true (geographic) north. The direction in which the compass needle points is referred to as magnetic north, and the angle between magnetic north and the true north direction is called **magnetic declination**. The terms "variation," "magnetic variation" or "compass variation" are often used in place of magnetic declination, especially by mariners.

Natural Resources Canada's Geomagnetic Website provides a Magnetic Declination Calculator that can calculate the magnetic declination for any location (given latitude, longitude and year) on the globe.

A chart of magnetic declination is provided for Canada based on the year 1995. Small changes from year to year do occur, but can be ignored for the purposes of this model. A magnetic declination of 10°W, means that magnetic north is 10° west of true north for that location and time.



Lines of Equal Magnetic Declination in Canada for 1995

Monthly Inputs

Monthly mean weather data are entered by the user in this section. The user also specifies the months or the fraction of months (e.g. 0.25 if the system is used only one week in a month) during which the solar energy equipment is used. All energy and cost calculations in the remainder of the Solar Air Heating Project workbook are performed for the period of use of solar energy only. In other words, months where no solar energy is used are not taken into account in

the energy and financial analysis, the rationale being that there is no energy displaced or solar savings to calculate for these months. For months where equipment is used only for a fraction of the entire month, the same fraction applies for that month to all energy calculations.

Some cells may be greyed out and written in italic to indicate that they are not used for energy calculations. For example, if the system is not used in the month of July (i.e. the "Fraction of month used" is zero for July), then weather data is not required for this month. Hence the corresponding cells are greyed out to indicate that the information is not required to run the model.

Fraction of month used

The user enters the months for which the energy equipment is used. Months during which the energy equipment is not used are not taken into account in the energy, financial analysis and GHG. For each month, the user enters a value between 0 and 1. 0 is entered if the energy equipment is not used during a month, 0.5 if it is used 50% of the time and 1 if it is used 100% of the time.

Monthly average daily radiation on horizontal surface

The user enters the amount of solar radiation received on average during one day on a horizontal surface at the site. Data in MJ/m²/d should be divided by 3.6 to be converted to kWh/m²/d. Data in BTU/ft² should be divided by 317 and data in cal/cm² or Langleys should be divided by 86 to be converted to kWh/m²/d. The user can consult the RETScreen Online Weather Database for more information.

The values range from 0 during polar night months in the polar regions, to values around 8.5 kWh/m²/d in temperate climates during summer months.

Monthly average temperature

The user enters the average temperature for the month. This temperature is used to estimate the performance of the solar air heating system and its delivered air temperature. The user can consult the RETScreen Online Weather Database for more information.

Monthly average wind speed

The user enters the average wind speed for the month. Although the free-stream wind speed is entered, the model adjusts for the wind sheltering effects of the building when calculating energy savings. The user can consult the RETScreen Online Weather Database for more information.

Monthly average daily radiation in plane of solar collector

The model calculates the amount of solar radiation received on average during one day on a tilted surface at the site, in kWh/m²/d. Typical values calculated by the model range from 0 to 10 kWh/m²/d.

Solar radiation (horizontal)

The model calculates the amount of solar radiation incident on a horizontal surface for the entire year and for the period (season) of use.

Solar radiation (tilted surface)

The model calculates the amount of solar radiation incident on the solar collector for the entire year and for the period (season) of use.

Average temperature

The model calculates the average ambient temperature for the entire year and for the period (season) of use.

Average wind speed

The model calculates the average wind speed for the entire year and for the period (season) of use.

Note: At this point, the user should return to the *Energy Model* worksheet.

Cost Analysis[1]

As part of the RETScreen Clean Energy Project Analysis Software, the *Cost Analysis* worksheet is used to help the user estimate costs associated with a solar air heating project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

Typically, the most cost effective installations of solar air heating systems for ventilation air applications occur in new construction since the cost of the solar air heating collector cladding can displace an expensive finished wall cladding material; and no additional ventilation fan is required. The second most cost effective installation is for retrofits when there are plans to either repair or upgrade an existing wall, improve indoor air quality, or add more ventilation or makeup air to balance exhaust air. However, it is certainly possible that high heating costs could make the solar air heating system financially attractive, even in retrofit situations that don't meet the above criteria.

The example indicates where the installation of the solar air heating system is "credited" for material and labour costs that would have been spent on the wall and air heating system had the solar heating not been utilised. The user will have to determine which initial cost items should be credited. It is likely that engineering and design costs could also be credited as some of the time required for these items would have to be incurred for the "conventional" building heating and cladding system. These "credits" can have a significant impact on the financial viability of a particular solar air heating project.

Type of analysis

The user selects the type of analysis by clicking on the appropriate radio button. For a "Pre-feasibility analysis," less detailed and lower accuracy information is typically required while for a "Feasibility analysis," more detailed and higher accuracy information is usually required.

To put this in context, when funding and financing organisations are presented with a request to fund an energy project, some of the first questions they will likely ask are "how accurate is the estimate, what are the possibilities for cost over-runs and how does it compare financially with other options?" These are very difficult to answer with any degree of confidence, since whoever prepared the estimate would have been faced with two conflicting requirements:

- Keep the project development costs low in case funding cannot be secured, or in case the project proves to be uneconomic when compared with other energy options.
- Spend additional money and time on engineering to more clearly delineate potential project costs and to more precisely estimate the amount of energy produced or energy saved.

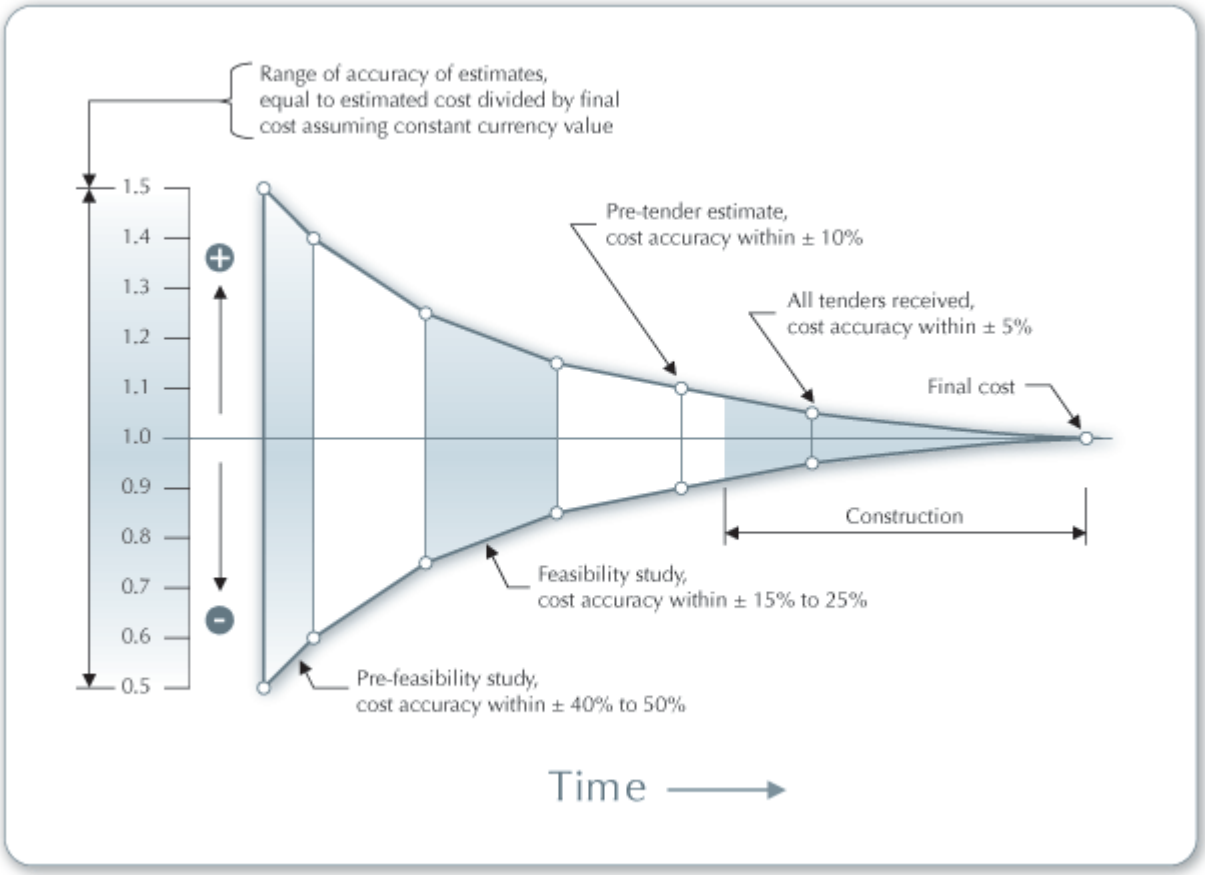
[1] A reminder to the user that the range of values for cost items mentioned in the manual are for a 2004 baseline year in Canadian dollars. Some of this data may be time sensitive so the user should verify current values where appropriate. (The approximate exchange rate from Canadian dollars to United States dollars was 1 CAD = 0.78 USD and to the Euro was 1 CAD = 0.61 EUR as of January 6, 2004).

To overcome, to some extent, such conflicts, the usual procedure is to advance the project through the following four stages:

- Pre-feasibility analysis
- Feasibility analysis
- Development (including financing) and engineering
- Construction and commissioning

Each stage could represent an increase of a magnitude or so in expenditure and a halving of the uncertainty in the project cost-estimate. This process is illustrated, for hydro projects, in the Accuracy of Project Cost Estimates figure [Gordon, 1989].

At the completion of each step, a "go or no go" decision is usually made by the project proponent as to whether to proceed to the next step of the development process. High quality, but low-cost, pre-feasibility and feasibility studies are critical to helping the project proponent "screen out" projects that do not make financial sense, as well as to help focus development and engineering efforts prior to construction. The RETScreen Clean Energy Project Analysis Software can be used to prepare both the initial pre-feasibility analysis and the more detailed feasibility analysis.



Accuracy of Project Cost Estimates [Gordon, 1989]

Currency

To perform a RETScreen project analysis, the user may select a currency of their choice from the "Currency" cell in the *Cost Analysis* worksheet.

The user selects the currency in which the monetary data of the project will be reported. For example, if the user selects "$," all monetary related items are expressed in $.

Selecting "User-defined" allows the user to specify the currency manually by entering a name or symbol in the additional input cell that appears adjacent to the currency switch cell. The currency may be expressed using a maximum of three characters ($US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. $ reduced by a factor of a thousand, hence k$ 1,000 instead of $ 1,000,000).

If "None" is selected, all monetary data are expressed without units. Hence, where monetary data is used together with other units (e.g. $/kWh) the currency code is replaced with a hyphen (-/kWh).

The user may also select a country to obtain the International Standard Organisation (ISO) three-letter country currency code. For example, if Afghanistan is selected from the currency switch drop-down list, all project monetary data are expressed in AFA. The first two letters of the country currency code refer to the name of the country (AF for Afghanistan), and the third letter to the name of the currency (A for Afghani).

For information purposes, the user may want to assign a portion of a project cost item in a second currency, to account for those costs that must be paid for in a currency other than the currency in which the project costs are reported. To assign a cost item in a second currency, the user must select the option "Second currency" from the "Cost references" drop-down list cell.

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can then increase the zoom to see those symbols correctly. Usually, symbols will be fully visible on printing even if not fully appearing on the screen display.

Cost references

The user selects the reference (from the *Cost Analysis* worksheet) that will be used as a guideline for the estimation of costs associated with the implementation of the project. This feature allows the user to change the "Quantity Range" and the "Unit Cost Range" columns. The options from the drop-down list are: "Canada - 2004," "None," "Second currency" and a selection of 8 user-defined options ("Enter new 1," "Enter new 2," etc.).

If the user selects "Canada - 2004" the range of values reported in the "Quantity Range" and "Unit Cost Range" columns are for a 2004 baseline year, for projects in Canada and in Canadian dollars. This is the default selection used in the built-in example in the original RETScreen file.

Selecting "None" hides the information presented in the "Quantity Range" and "Unit Cost Range" columns. The user may choose this option, for example, to minimise the amount of information printed in the final report.

If the user selects "Second currency" two additional input cells appear in the next row: "Second currency" and "Rate: 1st currency / 2nd currency." In addition, the "Quantity Range" and "Unit Cost Range" columns change to "% Foreign" and "Foreign Amount," respectively. This option allows the user to assign a portion of a project cost item in a second currency, to account for those costs that must be paid for in a currency other than the currency in which the project costs are reported. Note that this selection is for reference purposes only, and does not affect the calculations made in other worksheets.

If "Enter new 1" (or any of the other 8 selections) is selected, the user may manually enter quantity and cost information that is specific to the region in which the project is located and/or for a different cost base year. This selection thus allows the user to customise the information in the "Quantity Range" and "Unit Cost Range" columns. The user can also overwrite "Enter new 1" to enter a specific name (e.g. Japan - 2001) for a new set of unit cost and quantity ranges. The user may also evaluate a single project using different quantity and cost ranges; selecting a new range reference ("Enter new 1" to "Enter new 8") enables the user to keep track of different cost scenarios. Hence the user may retain a record of up to 8 different quantity and cost ranges that can be used in future RETScreen analyses and thus create a localised cost database.

Second currency

The user selects the second currency; this is the currency in which a portion of a project cost item will be paid for in the second currency specified by the user. The second currency option is activated by selecting "Second currency" in the "Cost references" drop-down list cell. This second unit of currency is displayed in the "Foreign Amount" column.

If the user selects "$," the unit of currency shown in the "Foreign Amount" column is "$."

Selecting "User-defined" allows the user to specify the currency manually by entering a name or symbol in the additional input cell that appears adjacent to the currency switch cell. The currency may be expressed using a maximum of three characters ($US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. $ reduced by a factor of a thousand, hence k$ 1,000 instead of $ 1,000,000).

If "None" is selected, no unit of currency is shown in the "Foreign Amount" column.

The user may also select a country to obtain the International Standard Organisation (ISO) three-letter country currency code. For example, if Afghanistan is selected from the currency switch drop-down list, the unit of currency shown in the "Foreign Amount" column is "AFA." The first two letters of the country currency code refer to the name of the country (AF for Afghanistan), and the third letter to the name of the currency (A for Afghani).

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can then increase the zoom to see those symbols correctly. Usually, symbols will be fully visible on printing even if not fully appearing on the screen display.

Rate: 1st currency / 2nd currency

The user enters the exchange rate between the currency selected in "Currency" and the currency selected in "Second currency." The exchange rate is used to calculate the values in the "Foreign Amount" column. Note that this selection is for reference purposes only, and does not affect the calculations made in other worksheets.

For example, the user selects the Afghanistan currency (AFA) as the currency in which the monetary data of the project is reported (i.e. selection made in "Currency" input cell) - this is the 1st currency. The user then selects United States currency (USD) from the "Second currency" input cell - this is the 2nd currency. The user then enters the exchange rate in the "Rate: AFA/USD" input cell i.e. the amount of AFA needed to purchase 1 USD. Using this feature the user can then specify what portion (in the "% Foreign" column) of a project cost item's costs will be paid for in USD.

% Foreign

The user enters the percentage of an item's costs that will be paid for in the second currency. The second currency is selected by the user in the "Second currency" cell.

Foreign Amount

The model calculates the amount of an item's costs that will be paid for in the second currency. This value is based on the exchange rate and the percentage of an items cost that will be paid for in the second currency, as specified by the user.

Initial Costs (Credits)

The initial costs associated with the implementation of a solar air heating project are detailed below. The major categories include costs for preparing a feasibility study, performing the project development functions, completing the necessary engineering, purchasing and installing the energy equipment, construction of the balance of equipment, and costs for any other miscellaneous items.

Feasibility Study

Once a potential cost-effective solar air heating project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility analysis study is normally required for larger solar air heating projects (greater than 100 m² of solar collectors). Feasibility studies typically include such items as a site investigation, a preliminary project design and

detailed cost estimate, and a final report. Feasibility study project management and travel costs are also normally incurred. These costs are detailed in the section below.

For smaller projects, the cost of the feasibility study, relative to the cost of the solar air heating system, may not be justified. In this case the project proponent may choose to go directly to the engineering stage (combining some steps from the feasibility and development stages). In some cases a client may not require a feasibility study and will only ask for a proposal from the supplier, relying on the supplier's energy saving estimates and price quotation. Some clients routinely specify a solar air heating system in new construction without a detailed analysis.

Note: The RETScreen Clean Energy Project Analysis Software can also be used to prepare the Feasibility Study.

Site investigation

When a solar air heating system is being considered for an existing building, a site visit is often required to evaluate the site conditions and suitability of installing the solar air heating system. If the solar air heating system is for a new building, then a site visit is not required since the analysis can be done from architectural or engineering drawings. Site visit time includes time required to arrange meetings, survey the site, obtain the necessary information and any travel time (but not travel expenses - see "Travel and accommodations" below).

A single site visit will suffice to conduct the feasibility study for the vast majority of retrofit projects. The cost of a site visit will be influenced by the planned duration and travel time to and from the site. The time required to gather the data prior to the site visit and during the site visit typically falls between 4 and 8 hours. For new construction, where a site visit is not normally required, estimate 2 to 4 hours to obtain drawings and required information. Solar air heating system expert fees typically range from $45/h to $110/h.

Preliminary design

A preliminary design is required to evaluate the building, determine the size, layout and potential energy output of the solar air heating system. After the solar air heating system is sized, draft drawings are then prepared. The preliminary design is then used to prepare a more detailed cost estimate.

The time required to prepare the preliminary design and detailed cost estimate typically falls between 8 and 12 hours per building at fees between $45/h to $110/h.

Report preparation

A summary report should be prepared which describes the feasibility study, its findings and recommendations. The written report will contain data summaries, charts, tables and illustrations which clearly describe the proposed project. This report should be in sufficient detail regarding costs, performance and risks to enable project lenders and other decision-makers to evaluate the merits of the project.

The cost of the report preparation is calculated based on an estimate of the time required by a professional to complete the necessary work, and should also include the time required to manage the overall feasibility study preparation. Preparing a feasibility study report takes between 8 and 20 hours. Use 8 hours for one building and 20 hours for 5 or more buildings per report, at a rate of between $45/h to $110/h.

Travel and accommodation

This cost item includes all travel related costs (excluding time) required to prepare all sections of the feasibility study by the various members of the feasibility study team. These expenses include such things as airfare, car rental, lodging and per diem rates for each trip required. For local travel, a supplier may not charge for time and expenses. For projects in isolated areas, where air travel is time consuming and expensive, it is better to include more than one potential project in the feasibility study to spread the site visit costs over a number of projects and not just one building. This is especially important where the buildings being evaluated are small in size with resulting small solar air heating systems.

In the case of isolated areas, rates for air travel will vary considerably. Airfares are typically twice those for similar distances in populated areas. Since travel is a large component of the cost of doing work in isolated areas and the range of cost so variable it is advised to contact a travel agent with experience in arranging such travel. Accommodation rates are typically twice the going rate for modest accommodation in populated areas. Typical rates for modest hotel rooms can range from $180 to $250 per day in the more isolated areas.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Development

Once a potential solar air heating project has been identified through the feasibility study (or sometimes only a pre-feasibility study) to be desirable to implement, project development

activities follow. For some projects, the feasibility study, development and engineering activities may proceed in parallel, depending on the risk and return acceptable to the project proponent.

For solar air heating projects, there are a number of possible project developers. Currently, a common approach is for the client to be the building owner with the developer being the local solar air heating system product supplier who provides complete design/build services. General contractors may also be the developer, purchasing the solar air heating system on behalf of the building owner. It is also possible that an Energy Services Company (ESCO) could be the project developer, where they purchase the solar air heating system and install it on a building owned by a third party in return receiving a portion of the annual energy savings/production. Estimating the costs of development phase will depend on the particular development arrangement established. Items here include costs for permits and approvals, project financing, project development management and any development related travel costs. These cost are detailed below.

Permits and approvals

A building and electrical permit may be required by local authorities for the construction of the project. The cost of acquiring the necessary permits and approvals is calculated based on an estimate of the time required to complete the necessary work. For a typical solar air heating project the permit acquisition and approval process could take between 4 and 8 hours at rates of between $45/h and $110/h for project development staff. The user can also add to the number of hours, or unit costs, an amount to cover the actual permit itself. Permit costs are usually minor relative to the total project cost.

Project financing

The time and effort required to arrange project financing will vary depending upon the project developer and client relationship. In most cases, where the client is the building owner and the developer is the product supplier, the project financing costs attributable to the project are minimal. The building owner will usually finance the project out of capital or O&M budgets and the product supplier will provide in-kind support as required to help arrange the client project financing. In the case of an ESCO developed project, much more effort will likely be required to arrange financing, negotiate an energy services contract with the building owner and prepare legal documents.

The cost to obtain project financing will range from 8 and 24 hours at a rate of between $65/h and $200/h. The lower end of the range is for building owner/product supplier developed projects. The higher end of the range applies to ESCO type projects.

Project management

The project management cost item should cover the estimated expenses of managing all phases of the development of the project.

The elapsed time for the development of a solar air heating project is relatively short. An entire project can certainly be developed within a one year time period with actual construction time only taking a few weeks, depending on the project scale. The project development management time will usually take between 20 and 40 hours at rates of between $55/h to $110/h.

Travel and accommodation

This cost item includes all travel related costs (excluding time) required to develop the project.

Other

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A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Engineering

The engineering phase includes costs for the solar air heating system design, structural design, tenders and contracting, and construction supervision. If the project is awarded on a design/build basis, then all of these costs would be from the equipment supplier or contractor responsible for the project. If the project is awarded by tender based on specifications prepared by a consultant, then there will be engineering charges from the consultant overseeing the project and perhaps the equipment supplier.

SAH system design

The system design includes the time required to design the solar air heating system, and prepare design drawings and specifications. For small projects (under 25 m²), "generic" installation drawings can often be used and there may not be a separate charge for design.

The time required to prepare the solar air heating system design and detailed drawings fall between 5 to 80 hours. Allow 5 hours for residential projects, 10 hours for small non-residential projects where "generic" drawings can be used (projects under 50 m²), and up to 80 hours when detailed design and installation drawings are required (generally for tendered projects and

retrofits over 100 m² in size). Solar air heating system design fees usually range from $45/h to $110/h.

Structural design

When the project is a large retrofit, additional engineering time may be necessary to evaluate the structural and wind loading concerns for the installation. On most projects it is not required.

The time required to prepare the solar air heating system structural design and detailed drawings will depend on the simplicity of the structural layout chosen and will range from 0 to 30 hours. Allow 0 for most small projects. Allow 20 to 30 hours for projects requiring detailed drawings and/or an engineer's stamp on the drawings. Structural design rates range from 55 to $110/h.

Tenders and contracting

Upon completion of the various engineering tasks, tender documents may be required by the project developer. They are prepared for the purpose of selecting contractors to undertake the work. Once tenders are released, the contracting process is required to both negotiate and establish contracts for the completion of the project.

The time required to produce a set of bid documents will vary depending upon the complexity and the size of the project. If bid documents are required, 20 to 40 hours at rates of $45/h to $110/h are common.

Construction supervision

The construction supervision cost item summarises the estimated costs associated with ensuring that the project is constructed as designed. The consultant overseeing the project, the equipment supplier or the project manager can each act as construction supervisor. Construction supervision involves regular visits to the job site to inspect the installation.

Depending of the project size, this task can take between 8 to 24 hours at rates of $45/h to $110/h. The quantity range for construction supervision is generally 1 to 2 trips to the sight for small projects. If it is a large installation which may take more than a month to install, this number could increase to 3 trips. Travel time to the site for commissioning are in addition to the range given. Travel costs should be included in the "Development" section above.

Other

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This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

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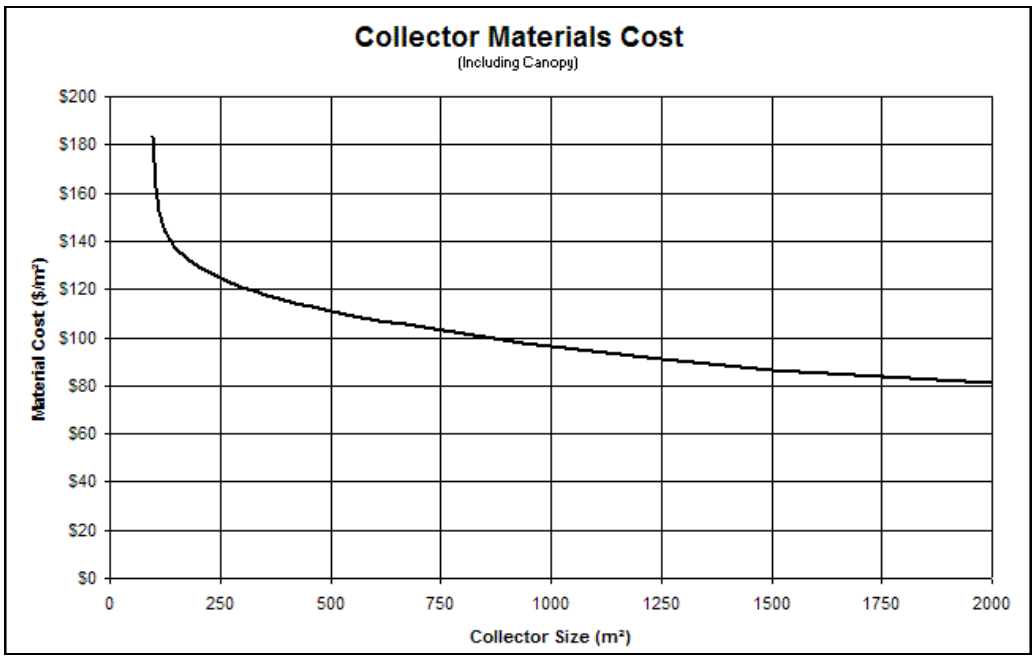
Energy Equipment

The energy equipment, as defined here, includes the solar air heating collector, their installation and any solar air heating system related transportation costs. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required. These costs are detailed below.

Solar collector materials

The final price for solar air heating collector materials will vary on a wide variety of factors specific to any individual installation. For the RETScreen project analysis items, site-specific factors need to be estimated by the user. The pricing ranges given below are based on various assumptions including a stock material profile, standard perforation patterns, black or dark brown colour galvanized steel, standard cladding supports. A canopy is assumed to be part of the installation. If specific concerns exist the manufacturer should be consulted for clarification and pricing advice. The graph below provides a starting point for calculating the costs for a typical installation. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.



Solar Collector Materials Cost

Equipment installation

Equipment installation refers to all the site labour required to install the solar collector component of the system. The user enters a price per area.

For large industrial projects with unobstructed walls, 1 hr/m² is typical. For smaller projects and those with numerous windows or doors or obstructions on the wall where the collector is to be installed, 1½ hr/m² is typical. In isolated areas where working conditions are generally more difficult, 2 hr/m² is typical. Hourly rates are approximately $35/h to $55/h. Thus the cost of installation is $35/m² to $110/m² of solar collector. When the installation contractor comes from outside the region, use the high end of this range.

Estimating installation costs in isolated areas is more difficult, both for the designer and the contractor, who may be unfamiliar with the new technology. The installation costs depend on the size of the project, location, whether union or non-union labour is used, and the complexity of the installation. Larger communities will have contractors or qualified personnel who can install the system. However, many smaller communities do not have these resources and it is necessary to bring in outside contractors. The smaller projects have a higher cost per square metre compared with installations in populated areas which tend to be larger. For very isolated areas, it is best to check to see if there are contractors in the community or whether they would come from out of town, as this will affect the cost.

Cladding material credit

The solar air heating system collector becomes the exterior finish and surface of the wall. It replaces the wall facade that would have been installed and a credit for displacing that material is to be included here. The amount of the credit includes all of the other costs such as hardware, etc. that are also allocated to the solar air heating system collector (cladding). If the building is existing and the wall is in excellent condition, and there is no need to reclad, then there may be no savings. If the wall needs repairs or it is a new building, there will be savings. The savings is based on the area of the solar collector.

In some cases, local contractors will know the cost of supplying and installing the conventional wall cladding. If a local price is not known, it can be estimated from the cost of the solar collector. Determine the cost of the solar collector cladding including the material and installation hardware per unit area. The unit cost of conventional metal cladding is typically 33 to 50% of the cost of the solar collector. The wall cladding "credit" will be deducted directly from the cost of the solar collector cost when entered into the worksheet.

Cladding labour credit

Where a credit is given for conventional wall cladding that would have been put on the building had the solar air heating system not been installed, a credit should likewise be provided for the installation. The labour credit is entered as a separate line item. For new construction 50% credit will usually be available because some form of sheathing is still required behind the collector. For retrofit situations the credit will be about 75% of the cost of installing the collector.

Incremental transportation

The transportation costs for the solar air heating system equipment vary depending on weight and size of material to be shipped and distance from the factory. Normally, the material is shipped by truck unless there is no road access to the site, in which case, other methods, such as rail, air, or boat are required. Some projects will require more than one freight carrier. For example, truck to rail line, then to a barge or plane. Each time the material is transferred, someone must be on hand to receive it and/or arrange for the transfer. Freight costs to isolated areas may be difficult to estimate and it is advisable to check for best routing.

A typical unit cost range for truck freight is $210 to $3,150 per project. For best estimates, contact a freight company and get an estimate for shipping. Each square metre of solar air heating system collector weighs approximately 4 kg/m² in aluminium and 7 kg/m² in galvanized steel. The weight of the collector itself should be augmented by 5 to 10% to account for crating. A rough estimate for the unit cost for air freight or combinations of travel modes is $1,050 to $5,250 per project.

Where a "credit" is to be given for the wall cladding substituted by the solar collector, the cost of cladding transport should be deducted from that of the solar collector. The only difference in weight or volume for final transport costs will be the support structure. Therefore, there may be a credit of 75% or more for the transport costs of the solar collector.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

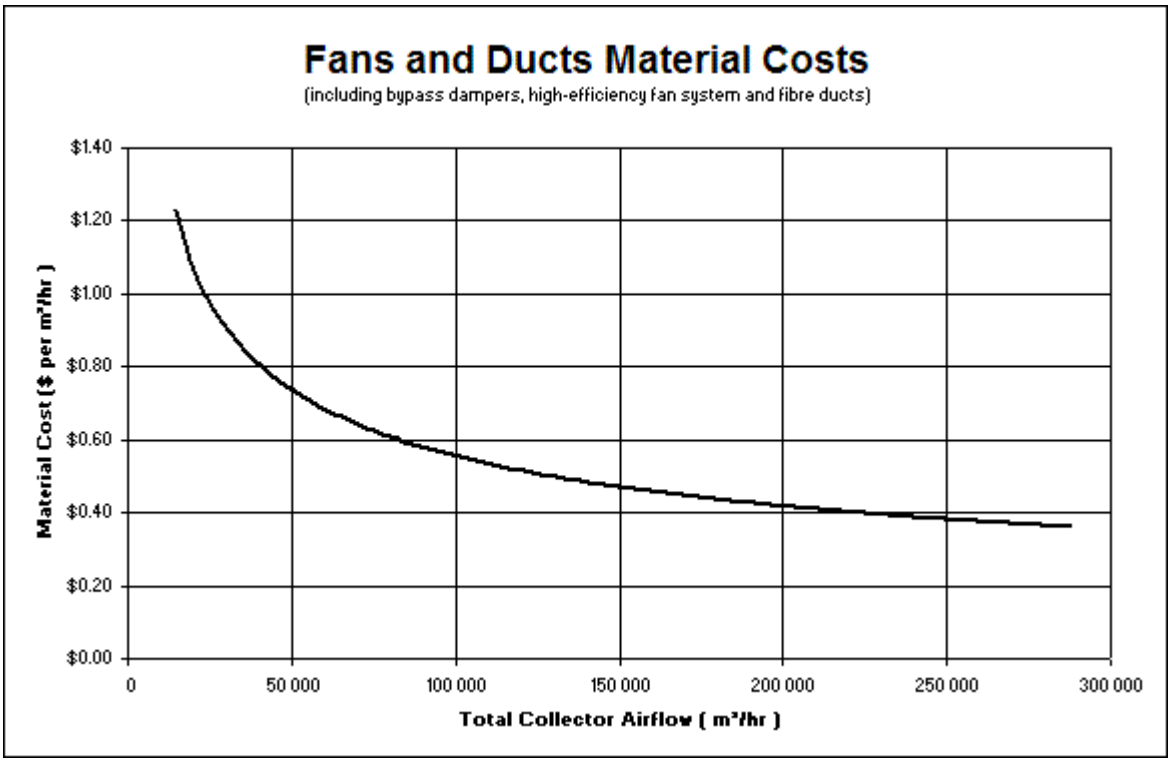
A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Balance of Equipment

The balance of equipment for a solar air heating project typically includes fans, ducting, recirculation dampers, equipment installation, electrical work and equipment transportation. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or any other information required. These costs are detailed below.

Fans and ducting materials

Fans and ducting materials are entered as a single item. The figure below provides initial values for fan and duct materials costs in industrial systems. The figure assumes that high-efficiency fans and fibre ducts are used.



Fans and Ducts Material Costs

If a different design is required the price can be adjusted. Pricing can also be built up from individual items listed in the Alternative costing method, or from information from knowledgeable contractors.

Fans and ducting labour

Fans and ducting labour are entered as a single item. Typically the labour cost is between 25 and 100% of the fan and ducting material cost. Use the lower value for simple installations where there are few obstructions to the fans and ducting. The higher value would be more appropriate in complex retrofit installations where there are many obstructions to avoid.

If a different design is required the price can be adjusted. Pricing can also be built up from individual items listed in the Alternative costing method, or from information from knowledgeable contractors.

Fans and ducting material credit

In some retrofit situations, the building has no makeup air system. If a makeup air system is needed, its cost, including freight, installation, and overhead, is to be credited against the costs detailed below. In some industrial projects, the solar air heating system fans and ducting may be less expensive than the steam or gas makeup air units that they replace and the credit here may be higher than the solar air heating fan cost estimated above.

Fans and ducting labour credit

If a conventional makeup air system exists or is not required, no credit is applied. In a situation where a conventional makeup system was to be retrofitted even if the solar air heating system is not installed, its cost should be credited. Local contractors may be able to supply a price for this system. As a rough estimate, the cost of the conventional makeup air system should be similar to the "Balance of Equipment" costs estimated above for the solar air heating system.

Incremental transportation

The user enters the additional freight costs. The same freight conditions that exist for the solar collector material exist for the fans, ducting, and dampers. If the fans or dampers are small, they may be able to be shipped by parcel post which can be a lower cost method for some regions.

The unit cost range for truck freight varies as described in the previous section. For best estimates, contact a freight company and get an estimate for shipping from the local Solarwall® distributor. The unit cost range for the small dampers, which can be shipped by parcel post or regular carrier, should be between $20 to $105 each. For larger fans, allow between $105 to $525 per fan and bypass damper to communities with regular freight service. Air freight or other means to isolated areas can be as high as $1,050 per fan and damper unit.

Other

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A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Miscellaneous

This category is for all of the miscellaneous costs that occur during a project and have not been taken into account in the previous sections. For solar air heating projects these costs can include contractors overhead, training and contingencies.

Overhead

A general contractor will apply a mark-up on their costs to cover overhead and on sub-contractors costs to cover contract administration. The overhead rate ranges from 0 to 30% of the entire project cost. Once the user has entered an overhead rate the RETScreen model calculates the overhead on the incremental costs of installing the solar air heating system.

Training

When the installation is complete, the system must be commissioned by the system designer often in the presence of the building owner. The commissioning involves a trip to the job site. This trip normally includes the final inspection and necessary training for the operation of the system. The adequate training of operators and maintenance personnel is fundamental to the successful deployment of any technology. This cost is usually small for solar air heating systems given their relative simplicity.

A 1 to 10 hour training session by a solar air heating system expert should be sufficient for the client to operate the solar air heating system properly. Rates for solar air heating system experts range from 45 to $110/h.

Contingencies

The allowance made for contingency costs depends on the level of accuracy of the cost estimates. Contingencies are estimated based on a user-selected percentage of the sub-total of all project costs. Note that contingencies are incremental in the sense that they are derived from project costs including any credits.

The allowance for contingency items should be based on the level of accuracy associated with the RETScreen pre-feasibility estimate of the project costs. Typically, a pre-feasibility level cost analysis should be accurate within 40 to 50%. However, this accuracy will depend on the expertise of the study team, the scale of the project being considered, the level of effort put forward to complete the pre-feasibility study and the availability of accurate information. Given the relative simplicity of solar air heating systems, it is certainly possible that the RETScreen user experienced with solar air heating systems could estimate costs in the range of 5 to 40% of the total initial project costs.

Annual Costs (Credits)

There might be some annual costs associated with solar air heating projects, but they are likely to be very small compared to the overall system cost. These will include property taxes and

insurance, O&M labour and travel and accommodation expenses. In addition, costs for contingencies and parasitic electricity consumption will also be incurred. These costs are detailed below.

O&M

Property taxes/Insurance

Generally, solar air heating systems should not increase property taxes. In some cases, a community may provide a tax incentive for solar air heating installations. The solar air heating system owner may choose to insure the cost of the system. This cost can be estimated by contacting an insurance broker.

O&M labour

The solar air heating system requires almost no maintenance. The material is all metal and the coating is designed to last over twenty years. If the fans exist, then there are no additional maintenance costs. If a new fan is supplied (that otherwise would not have been supplied), it will require annual maintenance. If a summer bypass damper is supplied, then it may require annual maintenance similar to other dampers in the ventilation system.

Unit cost for solar air heating system, existing fans, and a new fan that would have been installed with the ventilation system is 0. If a separate fan and/or bypass damper is required include a maintenance cost of $55 to $330 per year depending on the size and number of fans.

Travel and accommodation

In isolated areas, it is possible that an annual allowance may be required for travel, room and board costs associated with annual maintenance and inspection by a system expert.

Other

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A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The

user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Contingencies

A contingency allowance may be included to account for unforeseen annual expenses. This may include costs for replacement of solar collectors due to vandalism (if this item is not covered by the insurance policy) and other potential cost items. However, due to the durability of the solar air heating system these costs should be expected to be minimal. A contingency allowance of 1 to 5% of total solar collector and balance of equipment cost per year is reasonable and will depend upon the project location. If conventional steel or aluminium cladding would have been installed in any case, it is reasonable to assume a 0% contingency allowance for the solar air heating project.

Fuel/Electricity

In most cases, the solar air heating system uses existing fans with little increase in static pressure drop. When a new fan is supplied, there is an operating cost if the fan is supplemental to the building requirements. Electrical energy consumption is calculated in the *Energy Model* worksheet. The cost for electricity used should be based upon the rate paid by the building owner.

Periodic Costs (Credits)

This section is provided to allow the user to specify the periodic costs associated with the operation of the system over the project life. Grey input cells are provided to allow the user to enter the name of a periodic cost and periodic credit item. The user must enter a positive numerical value in the "Unit Cost" column.

A periodic cost represents recurrent costs that must be incurred at regular intervals to maintain the project in working condition. A periodic cost item is entered in the grey input cell. The user then selects "Cost" from the drop-down list in the unit column. The interval (in years) over which the periodic cost is incurred is entered in the period column. The amount of the cost incurred at each interval is entered in the unit cost column.

The project may also be credited for periodic costs that would have been incurred over the project life of the base case, or conventional, energy system. The periodic credit item is entered in the grey input cell. The user then selects "Credit" from the drop-down list in the unit column. The interval (in years) over which the periodic credit is incurred is entered in the period column. The amount of the credit incurred at each interval is entered in the unit cost column. Note that the credit item is expressed as a negative value in the "Amount" column.

End of project life

The user enters the value of the project at the end of its life. This amount is also commonly referred to as the salvage value (or disposal value). If the salvage value of the project at the end

of its life is positive, then the user selects "Credit" from the drop-down list in the unit column in order to express this item as a negative value. However, if the costs of remediation or decommissioning that must be incurred at the end of the project life exceed the salvage value, then the user must select "Cost" from the drop-down list. The user must enter a positive numerical value in the "Unit Cost" column.

Note: At this point, the user should go to the optional *GHG Analysis* worksheet.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

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Alternative costing method

Fan materials

The ideal situation is a building with an existing ventilation air system and intake located on the wall facing the equator, or in new construction, the ability to specify a south (or north in Southern hemisphere) wall air intake. In these cases, the existing or proposed may be suitable at a minimal additional cost (e.g. a new belt or motor required). There are two cases when fan costs should be included. Retrofit projects where there is no makeup air system (only exhaust fans) and large projects (over 200 m² of of solar collector area) where it would be beneficial to have more than one fan. The capacity of the fan determines the depth of the air cavity between the existing wall and the solar collector cladding.

The type of fan and auxiliary equipment affects the cost. Some type of control is necessary to handle the wide range of temperatures that enter the fan unit. Either the volume of air entering the building must vary or the system must have an auxiliary heater to bring the outside air to room temperature when there is insufficient solar heat. If a new fan is being added, the fan unit should have either modulating dampers to blend return air with fresh air, a variable speed fan control, or a back-up heater.

Typically one fan is used for every 100 to 250 m² of solar collector or for every 7,200 to 36,000 m³/h of air flow. The cost range for small fans is $0.40 to $0.65 per m³/h of air flow. For example, a 40 m² solar collector area with 70 m^3/h per m² of air needs a fan costing 40 x 70 x 0.60 = $1,680. The cost range for larger fans with mixing dampers is $0.30 to $0.45 per m³/h of air flow.

Ducting materials and labour

Two types of ducting can be required: ducting before the fan and ducting after the fan. In most commercial and residential retrofit cases, duct work after the fan exists and there are no additional costs for this duct work. Similarly for new commercial construction, duct work after the fan would have been required if a conventional ventilation system were installed and there is no additional cost associated with the solar air heating system. If the ventilation air intake is not mounted on the wall facing the equator, then ducting is required to connect the solar collectors to the intake. If the intake is on the wall facing the equator, then no additional ducting is required.

The size of the duct is dependent on the volume of air flowing through it. All ducting before the fan must be insulated rigid ducting to prevent condensation from occurring. Ducting after the fan does not require insulation and can be either rigid or lower cost flexible fibre ducting.

The duct between the wall and the fan should be as short as possible. Ducting after the fan will be long enough to distribute air throughout the area to be ventilated. Unit cost range for insulated ducting between the wall and fan is $60 to $200/m. For ducting after the fan, allow between $60 to $200/m for metal ducting and between $70 to $240/m for non-rigid ducting. These unit costs also include installation since ducting is normally provided on a supply and install basis.

Bypass dampers

A summer bypass damper is used to allow unheated fresh air to enter the system during the summer months when heating is not required. Bypass dampers are not required if the system is not to be operated during the summer months (e.g. schools) or there is a year round heating requirement. One bypass damper is used per fan and can be located either on the solar collector in front of the fan, or in the duct work between the fan and solar collector.

The unit cost range for each damper is $25 to $110 for small manually operated residential type dampers. For motorized thermostatically controlled dampers, the unit cost range is $525 to $1,600 each depending on the size of the fan.

Equipment installation

Equipment installation costs need to be calculated for the various components and the total entered. The same factors that apply to the installation of the solar collector apply to the installation of the mechanical equipment. If the existing fan can be used and it is located on the wall facing the equator, then there is no need to have a separate mechanical contractor (all work can be done by the general contractor).

To install a small fan requires approximately 2 hours. Larger fans which may require a mechanical contractor will require more time and can take between 8 to 20 hours per fan depending on the size, complexity, and fan location. Bypass dampers would normally be installed with the solar collector cladding material in 3 to 6 hours each. If the contractor is not local, there would be additional travel time and expenses. Thus, the cost to install a fan and bypass damper can range from $220 for small fans using local labour to $2,200 for large fans using outside labour.

The cost of installing ducting depends on the complexity of the project. Buildings with high ceilings and a large number of obstructions in the ceiling will have greater installation costs. The estimate will require time to make an opening in the wall, installing, sealing and insulating metal ducting between the building wall and the fan, and installing the supply air duct from the fan outlet into the building. Obstructions will require the installation of transitions, offsets, or other sheet metal work, all of which adds cost. Installation time can generally range from 20 person-hours per fan system for simple locations with low ceilings to over 100 person-hours for fan systems under difficult site conditions.

Electrical

There is no electrical work required for the solar air heating collector or for an existing fan. If a new fan is to be installed or a motorised bypass damper is required, then there is electrical work. For residential applications, the electrical work may be performed by the mechanical contractor or person installing the solar collectors. If local electricians are not available, the costs will be higher. Commercial projects require an electrician and the wiring is normally done in conduit. Fans over 1 HP size may require motor starters and separate on/off controls at the floor level as well as a disconnect at the fan. Any special controls or monitoring equipment are included in this item.

Electrical work on non residential applications can take between 20 to 40 hours per fan and between 6 to 10 hours per bypass damper. Residential projects should require between 1 to 4 hours of work. Applying typical labour rates to these times, the electrical cost for each fan/damper set ranges from $220 to $4,400.

Financial Summary

As part of the RETScreen Clean Energy Project Analysis Software, a *Financial Summary* worksheet is provided for each project evaluated. This common financial analysis worksheet contains six sections: **Annual Energy Balance**, **Financial Parameters**, **Project Costs and Savings**, **Financial Feasibility, Yearly Cash Flows** and **Cumulative Cash Flows Graph**. The Annual Energy Balance and the Project Costs and Savings sections provide a summary of the *Energy Model*, *Cost Analysis* and *GHG Analysis* worksheets associated with each project studied. In addition to this summary information, the Financial Feasibility section provides financial indicators of the project analysed, based on the data entered by the user in the Financial Parameters section. The Yearly Cash Flows section allows the user to visualise the stream of pre-tax, after-tax and cumulative cash flows over the project life. The *Financial Summary* worksheet of each Workbook file has been developed with a common framework so the task of the user in analysing the viability of different project types is made simpler. This also means the description of each parameter is common for most of the items appearing in the worksheet.

One of the primary benefits of using the RETScreen software is that it **facilitates the project evaluation process for decision-makers**. The *Financial Summary* worksheet, with its financial parameters input items (e.g. avoided cost of energy, discount rate, debt ratio, etc.), and its calculated financial feasibility output items (e.g. IRR, simple payback, NPV etc.), allows the project decision-maker to consider various financial parameters with relative ease. A description of these items, including comments regarding their relevance to the preliminary feasibility analysis, is included below.

Annual Energy Balance

The summary items here are calculated and/or entered in the *Energy Model* and *GHG Analysis* worksheets and transferred to the *Financial Summary* worksheet.

Project name

The user-defined project name is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Financial Summary*.

Project location

The user-defined project location is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Financial Summary*.

Renewable energy delivered

The *Energy Model* worksheet calculates the renewable energy delivered (MWh), which is equivalent to the heating energy delivered by the project. This energy displaces the heating energy that would have otherwise been delivered by the base case heating system. The heating

energy delivered is used in conjunction with the avoided cost of heating energy and the base case heating system seasonal efficiency to calculate the heating energy savings.

Heating fuel displaced

The heating fuel displaced is the type of heating energy displaced by the addition of the project. The heating fuel type selected in the *Energy Model* worksheet is copied automatically here. The heating fuel displaced is used in the calculation of the heating energy savings.

Electricity required

The *Energy Model* worksheet calculates the incremental fan energy required (MWh) for the solar air heating system during heating seasons. This value is then used to calculate the annual cost of fuel/electricity.

Net GHG emission reduction

The model calculates the net annual average GHG emission reduction in equivalent tonnes of CO_2 per year (t_{CO2}/yr) resulting from the implementation of the project instead of the base case, or baseline, heating system. This value is calculated in the *GHG Analysis* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

Net GHG emission reduction - credit duration

The model calculates the cumulative net greenhouse gas (GHG) emission reduction for the duration of the GHG credit, in equivalent tonnes of CO_2 (t_{CO2}), resulting from the implementation of the project instead of the base case, or baseline, system. This value is calculated by multiplying the appropriate net annual GHG emission reduction by the GHG reduction credit duration.

Net GHG emission reduction - project life

The model calculates the cumulative net GHG emission reduction for the duration of the project, in equivalent tonnes of CO_2 (t_{CO2}) resulting from the implementation of the project instead of the base case, or baseline, heating system. This value is calculated by multiplying the net annual GHG emission reduction by the project life.

Financial Parameters

The items entered here are used to perform calculations in this *Financial Summary* worksheet. Values for each parameter will depend on the perspective of the user (e.g. building owner vs. energy services company (ESCO)).

Avoided cost of heating energy

The user enters the cost of the heating energy displaced by the solar air heating system. For example, if "Diesel (#2 oil)-L" was selected as the base case heating system in the *Energy Model* worksheet, then the user must enter the local cost of diesel (#2 oil) fuel in $/L as the avoided cost of heating energy.

The avoided cost of heating energy is used in conjunction with the heating energy delivered, the heating value and the base case heating system seasonal efficiency (appearing in the *Energy Model* worksheet) to calculate the annual heating energy savings. The model escalates the avoided cost of heating energy yearly according to the energy cost escalation rate starting from year 1 and throughout the project life. Note that the avoided cost of heating energy unit for propane is expressed in terms of liquefied propane.

GHG emission reduction credit

The user enters the GHG emission reduction credit per tonne of CO_2 (t_{CO2}). It is used in conjunction with the net GHG emission reduction to calculate the annual GHG emission reduction income.

Preliminary estimates predict the market price of GHG emission reduction credits in the USA will range from $US 4 to $US 95 per tonne of CO_2, with $ 5 to $ 8 per tonne being the most likely range [Sandor, 1999]. As of 2003, the global market price has typically been in the range of $US 3 to $US 5 per tonne of CO_2.

The value entered is assumed to be representative of year 0, i.e. the development year prior to the first year of operation (year 1). The model escalates the GHG emission reduction credit value yearly according to the GHG credit escalation rate starting from year 1 and throughout the project life.

GHG reduction credit duration

The user enters the GHG reduction credit duration (year). This value typically represents the number of years for which the project receives GHG reduction credits. It is used to determine the annual GHG reduction income.

GHG credit escalation rate

The user enters the GHG credit escalation rate (%), which is the projected annual average rate of increase in the GHG emission reduction credit over the life of the project. This permits the user to apply rates of inflation to the market price of GHG emission reduction credits which may be different from general inflation.

Retail price of electricity

The retail price of electricity is copied automatically from the *Cost Analysis* worksheet. This value is used in conjunction with the electricity required to run the fan of the solar air heating system in order to calculate the system annual cost of fuel/electricity.

This value is assumed to be representative of year 0, i.e. the development year prior to the first year of operation (year 1). The model escalates the retail price of electricity yearly according to the energy cost escalation rate starting from year 1 and throughout the project life.

Energy cost escalation rate

The user enters the energy cost escalation rate (%), which is the projected annual average rate of increase for the cost of energy over the life of the project. This permits the user to apply rates of inflation to fuel/electricity costs which are different from general inflation for other costs. For example, North American electric utilities currently use energy cost escalation rates ranging anywhere from 0 to 5% with 2 to 3% being the most common values.

Inflation

The user enters the inflation rate (%), which is the projected annual average rate of inflation over the life of the project. For example, inflation for the next 25 years in North America is currently forecasted to range between 2 and 3%.

Discount rate

The user enters the discount rate (%), which is the rate used to discount future cash flows in order to obtain their present value. The rate generally viewed as being most appropriate is an organisation's weighted average cost of capital. An organisation's cost of capital is not simply the interest rate that it must pay for long-term debt. Rather, cost of capital is a broad concept involving a blending of the costs of all sources of investment funds, both debt and equity. The discount rate used to assess the financial feasibility of a given project is sometimes called the "hurdle rate," the "cut-off rate," or the "required rate of return." The model uses the discount rate to calculate the annual life cycle savings. For example, North American electric utilities currently use discount rates ranging anywhere from 3 to 18% with 6 to 11% being the most common values.

Project life

The user enters the project life (year), which is the duration over which the financial feasibility of the project is evaluated. Depending on circumstances, it can correspond to the life expectancy of the energy equipment, the term of the debt, or the duration of a heat purchase or energy service agreement. Although the model can analyse project life's up to 50 years, the project life of a well designed solar air heating system typically falls between 20 and 30 years.

Debt ratio

The user enters the debt ratio (%), which is the ratio of debt over the sum of the debt and the equity of a project. The debt ratio reflects the financial leverage created for a project; the higher the debt ratio, the larger the financial leverage. The model uses the debt ratio to calculate the equity investment that is required to finance the project. For example, debt ratios typically range anywhere from 0 to 90% with 50 to 90% being the most common. In cases where the solar air heating system cost is incorporated into the cost of a house or building and tied to its mortgage, the debt ratio will likely be between 50 and 75%.

Debt interest rate

The user enters the debt interest rate (%), which is the annual rate of interest paid to the debt holder at the end of each year of the term of the debt. The model uses the debt interest rate to calculate the debt payments. For example, at a minimum the debt interest rate will correspond to the yield of government bonds with the same term as the debt term. A premium is normally added to this rate (the "spread") to reflect the perceived risk of the project.

Debt term

The user enters the debt term (year), which is the number of years over which the debt is repaid. The debt term is either equal to, or shorter than the project life. Generally, the longer the term, the more the financial viability of an energy project improves. The model uses the debt term in the calculation of the debt payments and the yearly cash flows. The term of the debt normally falls within a 1 to 25 year range. It should not exceed the estimated project life.

Income tax analysis?

The user indicates by selecting from the drop-down list whether or not income tax should be factored into the financial analysis. If the user selects "Yes" certain input fields will be added to allow the user to customise the income tax analysis according to the specific circumstances of the project. In some situations, the after-tax return of a project can be more attractive than its pre-tax return. For solar air heating systems installed in private homes and paid for by the home-owner, it is likely that the user would select "No" given all cash flows would come from after-tax money.

The income tax analysis allows the model to calculate after-tax cash flows and after-tax financial indicators. In all cases, the model assumes a single income tax rate valid throughout the project life and applied to net income. Note that the analysis is based, among others, on net initial and annual costs, i.e. any credits entered in the *Cost Analysis* worksheet for these two categories are not treated separately. This leads to a reasonably accurate tax analysis unless the initial and/or annual credits are of the same order of magnitude as the corresponding costs and fall under a different depreciation schedule for tax purposes.

Effective income tax rate

The user enters the effective income tax rate (%), which is the effective equivalent rate at which the net income derived from the project is taxed. For example, in most jurisdictions, this would correspond to the combined federal, provincial /state and/or local income tax rates for businesses. Net taxable income is derived from the project cash inflows and outflows assuming that all revenues and expenses are paid at the end of the year in which they are earned or incurred.

The effective income tax rate is assumed to be constant throughout the project life. Note that sales tax should be considered in the "Initial Costs" section of the *Cost Analysis* worksheet and that property tax should be considered in the "Annual Costs" section.

Loss carryforward?

The user indicates by selecting from the drop-down list whether or not losses are carried forward, i.e. whether or not a loss (a negative taxable income) in a given year can be used to lower taxes owed in that same year or can be deferred to offset profits from future years. If the user selects "Yes," losses are carried forward and applied against taxable income in the following years, thereby reducing the income tax owed up to the accumulated losses, years after the losses occur. If the user selects "No," losses are not carried forward but rather lost and thereby never used to offset any other year taxable income. If the user selects "Flow-through," losses are not carried forward but rather used in the year in which they occur and applied against profits from sources other than the project (or qualify and generate a refundable tax credit), thereby reducing the income tax owed in the years in which losses occur.

Whether losses must be carried forward or not will depend on the tax laws in the jurisdiction in which the project is located. The "Flow-through" situation is typically the most advantageous for the project owner and can contribute to make profitable a project which would not appear financially attractive on a pre-tax basis.

The model does not allow losses to be carried backward and does not set a limit on the number of years for carryforwards.

Depreciation method

The user selects the depreciation method from three options in the drop-down list: "None," "Declining balance" and "Straight-line." This selection of the yearly depreciation of assets is used in the model in the calculation of income taxes and after-tax financial indicators. The user should select the method accepted by the tax departments in the jurisdiction of the project. The difference between the "End of project life" value and its undepreciated capital costs at the end of the project life is treated as income if positive and as a loss if negative.

When "None" is selected, the model assumes that the project is fully capitalised at inception, is not depreciated through the years and therefore maintains its undepreciated value throughout its life.

When "Declining balance" is selected, the model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated at the depreciation rate. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0.

When "Straight line" is selected, the model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated with a constant rate over the depreciation period. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0.

For both declining balance and straight-line depreciation, the model assumes that the full depreciation allowed for a given year is always taken. Also, the model does not incorporate the half-year rule used in some countries and according to which depreciation is calculated over only half of the capitalised cost during the first year of operation of the equipment.

Depreciation tax basis

The user enters the depreciation tax basis (%), which is used to specify which portion of the initial costs are capitalised and can be depreciated for tax purposes. The remaining portion is deemed to be fully expensed during the year of construction (year 0).

For example, if a project costs $20,000 to evaluate (feasibility study) and develop, and $80,000 to design (engineering), build, install and commission, the user could enter 80% as the depreciation tax basis in order to depreciate only the engineering, energy equipment, balance of equipment and miscellaneous costs while the feasibility and development costs would be fully expensed during year 0.

Depreciation rate

The user enters the depreciation rate (%), which is the rate at which the undepreciated capital cost of the project is depreciated each year. The depreciation rate can vary widely according to the lass of assets considered and the jurisdiction in which the project is located.

Depreciation period

The user enters the depreciation period (year), which is the period over which the project capital costs are depreciated using a constant rate. The depreciation period can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

Tax holiday available?

The user indicates by selecting from the drop-down list whether or not the project can benefit from a tax holiday. If the user selects "Yes," the tax holiday applies starting in the first year of operation, year 1, up to the tax holiday duration. The income tax calculation for the development/construction year, year 0, is not affected.

Tax holiday duration

The user enters the tax holiday duration (year), which is the number of years over which the tax holiday applies, starting in the first year of operation, year 1. For example, in India, certain renewable energy projects are given a five-year tax holiday.

Project Costs and Savings

Most of the summary items here are calculated and/or entered in the *Cost Analysis* worksheet and transferred to the *Financial Summary* worksheet. Some calculations are made in the *Financial Summary* worksheet.

Initial Costs

The total initial costs represent the total investment that must be made to bring a project on line, before it begins to generate savings (or income). The total initial costs are the sum of the estimated feasibility study, development, engineering, energy equipment, balance of equipment and miscellaneous costs and are inputs in the calculation of the simple payback, the net present value and the project equity and debt.

It is important to note that the range of possible costs listed throughout RETScreen **do not include sales taxes**. In a number of jurisdictions, clean energy project costs are often exempt from sales taxes. Users will have to consider these costs for their region when preparing their evaluations. For example, if in a particular region sales tax is applicable to the cost of a solar air heating project then the user must add the amount of sales tax to the cost of the project chosen from the proposed range of values.

Feasibility study

The feasibility study item represents the sum of the costs incurred to assess the feasibility of a project. It is net of any "credits" for not having to develop the base case project. Considerable detail is provided in the *Cost Analysis* worksheet for estimating the sub-costs for feasibility studies. This is done because it will help the project proponent better estimate the costs of the next investment required, which is the investment in a feasibility study. However for smaller projects, the RETScreen analysis may be sufficient to move to the development and engineering phase or to construction.

Note: The RETScreen Clean Energy Project Analysis Software can also be used to prepare the Feasibility Study.

Development

The development item typically represents the sum of the costs incurred to bring a project to the detailed design and construction stage, once its feasibility has been proven. It is net of any "credits" for not having to develop the base case project.

Engineering

The engineering item typically represents the sum of the costs of the design activities required to go from the development stage to the construction stage of a project. It also includes costs for construction supervision. It is net of any "credits" for not having to develop the base case project.

Energy equipment

The energy equipment item typically represents the sum of the purchasing and installation costs of the energy equipment, less any "credits" for not having to purchase or install base case equipment.

Balance of equipment

The balance of equipment item represents the sum of the purchasing, construction and installation costs of all the elements of the energy system other than the energy equipment costs less any "credits" for not having to purchase or install base case equipment.

Miscellaneous

The miscellaneous item includes all the costs not considered in any of the other initial costs categories that are required to bring a project to the operational stage.

Incentives/Grants

The user enters the financial incentive; this is any contribution, grant, subsidy, etc. that is paid for the initial cost (excluding credits) of the project. The incentive is deemed not to be refundable and is treated as income during the development/construction year, year 0, for income tax purposes.

For example, in Canada the Renewable Energy Deployment Initiative (REDI) may provide a 25% contribution for certain renewable energy systems used for heating and cooling applications. The contribution is 40% for systems installed in Canada's remote communities. More information may be obtained from the REDI Website or by calling 1-877-722-6600.

Annual Costs and Debt

The total annual costs are calculated by the model and represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M costs, the fuel/electricity costs and debt payments. Note that the total annual costs include the reimbursement of the "principal" portion of the debt which is not, strictly speaking, a cost but rather an outflow of cash. These costs are described briefly below.

O&M

The operation and maintenance (O&M) costs are the sum of the annual costs that must be incurred to operate and maintain the energy system, in excess of the O&M cost required by the base case energy system. The model uses the O&M cost to calculate the total annual costs and the yearly cash flows.

Fuel/Electricity

The annual cost of fuel/electricity to run the solar air heating system is copied automatically from the *Cost Analysis* worksheet. It represents the incremental costs of electricity required to run the fans.

Debt payments - debt term

The model calculates the debt payments, which is the sum of the principal and interest paid yearly to service the debt. Whereas debt payments are constant over the debt term, the principal portion increases and the interest portion decreases with time. In that respect, it is similar to the yearly annuity paid to reimburse the mortgage of a house. Debt payments are calculated using the debt interest rate, the debt term and the project debt.

Annual Savings or Income

The total annual savings represent the yearly savings realised due to the implementation of the project. From the perspective of an energy services company, these "savings" will be viewed as "income." It is directly related to the avoided cost of heating energy derived from implementing the project.

Heating energy savings/income

The model calculates the heating energy savings which represent the additional cost that would have been incurred if this heating energy had been delivered by the base case energy system. The heating energy savings are equal to the product of the heating energy delivered, the heating value of the base case system, the avoided cost of heating energy divided by the base case heating system seasonal efficiency. The yearly value of heating energy savings is escalated at the energy cost escalation rate.

GHG reduction income - duration

The model calculates the GHG emission reduction income which represents the income (or savings) generated by the sale or exchange of the GHG emission reduction credits. It is calculated from the annual net GHG emission reduction and the GHG emission reduction credit value. The yearly value of GHG emission reduction income is escalated at the GHG credit escalation rate.

Periodic Costs (Credits)

End of project life - Cost/Credit

The value of the project at the end of its life entered by the user in the *Cost Analysis* worksheet is transferred here. This amount is also commonly referred to as the salvage value (or disposal value).

The salvage value entered is assumed to be representative of year 0, i.e. the development/construction year prior to the first year of operation (year 1). The model escalates the salvage value yearly according to inflation rate starting from year 1 and up to the end of the project life (i.e. the schedule year reported in the model).

For tax purposes, the difference between the project salvage value and its undepreciated capital costs at the end of the project life is treated as income if positive and as a loss if negative.

Financial Feasibility

The results provide the decision-maker with various financial indicators for the proposed project.

Pre-tax Internal Rate of Return and Return on Investment

The model calculates the pre-tax internal rate of return (%), which represents the true interest yield provided by the project equity over its life before income tax. It is also referred to as the return on investment (equity) (ROI) or the time-adjusted rate of return. It is calculated by finding the discount rate that causes the net present value of the project to be equal to zero. Hence, it is not necessary to establish the discount rate of an organisation to use this indicator. An organisation interested in a project can compare the internal rate of return of the project to its required rate of return (often, the cost of capital). The IRR is calculated on a nominal basis, that is including inflation.

If the internal rate of return of the project is equal to or greater than the required rate of return of the organisation, then the project will likely be considered financially acceptable (assuming equal risk). If it is less than the required rate of return, the project is typically rejected. An organisation may have multiple required rates of return that will vary according to the perceived risk of the projects. The most obvious advantage of using the internal rate of return indicator to evaluate a project is that the outcome does not depend on a discount rate that is specific to a given organisation. Instead, the IRR obtained is specific to the project and applies to all investors in the project. The model uses the pre-tax yearly cash flows and the project life to calculate the internal rate of return.

After-tax Internal Rate of Return and Return on Investment

The model calculates the after-tax internal rate of return (%), which represents the true interest yield provided by the project equity over its life. It is also referred to as the return on investment

(equity) (ROI) or the time-adjusted rate of return. It is calculated by finding the discount rate that causes the net present value of the project to be equal to zero. Hence, it is not necessary to establish the discount rate of an organisation to use this indicator. An organisation interested in a project can compare the internal rate of return of the project to its required rate of return (often, the cost of capital). The IRR is calculated on a nominal basis, that is including inflation.

If the internal rate of return of the project is equal to or greater than the required rate of return of the organisation, then the project will likely be considered financially acceptable (assuming equal risk). If it is less than the required rate of return, the project is typically rejected. An organisation may have multiple required rates of return that will vary according to the perceived risk of the projects. The most obvious advantage of using the internal rate of return indicator to evaluate a project is that the outcome does not depend on a discount rate that is specific to a given organisation. Instead, the IRR obtained is specific to the project and applies to all investors in the project. The model uses the after-tax yearly cash flows and the project life to calculate the internal rate of return.

Simple Payback

The model calculates the simple payback (year), which represents the length of time that it takes for an investment project to recoup its own initial cost, out of the cash receipts it generates. The basic premise of the payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment. For example, in the case of the implementation of a solar air heating project, a negative payback period would be an indication that the annual costs incurred are higher than the annual savings generated.

The simple payback method is not a measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another. **The simple payback should not be used as the primary indicator to evaluate a project**. It is useful, however, as a secondary indicator to indicate the level of risk of an investment. A further criticism of the simple payback method is that it does not consider the time value of money, nor the impact of inflation on the costs.

On the other hand, the payback period is often of great importance to smaller firms that may be cash poor. When a firm is cash poor, a project with a short payback period, but a low rate of return, might be preferred over another project with a high rate of repayment, but a long payback period. The reason is that the organisation might simply need a faster return of its cash investment. The model uses the total initial costs, the total annual costs (excluding debt payments) and the total annual savings, in order to calculate the simple payback. The calculation is based on pre-tax amounts and includes any initial cost incentives.

Year-to-positive cash flow

The model calculates the number of years to positive (cumulative) cash flow, which represents the length of time that it takes for the owner of a project to recoup its own initial investment out of the project cash flows generated. The year-to-positive cash flow considers project cash flows

following the first year as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The model uses the year number and the cumulative after-tax cash flows in order to calculate this value.

The year-to-positive cash flow differs from the discounted payback indicator in that it considers the nominal value of future cash flows rather than the discounted value of future cash flows.

Net Present Value - NPV

The model calculates the net present value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. NPV is thus calculated at a time 0 corresponding to the junction of the end of year 0 and the beginning of year 1. Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with an investment project. The difference between the present value of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project. In using the net present value method, it is necessary to choose a rate for discounting cash flows to present value. As a practical matter, organisations put much time and study into the choice of a discount rate. The model calculates the NPV using the cumulative after-tax cash flows. In cases where the user has selected not to conduct a tax analysis, the NPV calculated will be that of the pre-tax cash flows.

Annual Life Cycle Savings

The model calculates the annual life cycle savings (ALCS) which is the levelized nominal yearly savings having exactly the same life and net present value as the project. The annual life cycle savings are calculated using the net present value, the discount rate and the project life.

Benefit-Cost (B-C) ratio

The model calculates the net benefit-cost (B-C) ratio, which is the ratio of the net benefits to costs of the project. Net benefits represent the present value of annual revenues (or savings) less annual costs, while the cost is defined as the project equity.

Ratios greater than 1 are indicative of profitable projects. The net benefit-cost (B-C) ratio, similar to the profitability index, leads to the same conclusion as the net present value indicator.

Calculate GHG reduction cost?

The user indicates by selecting from the drop-down list whether or not the project GHG emission reduction cost should be calculated. In order to calculate the true economic (not financial) cost of GHG emission reductions, a number of other parameters, such as the GHG emission reduction credit, debt ratio, etc. should be set to 0. In addition "Income tax analysis" should be set to "No" and other taxes should also be set to 0. This option is more applicable to economists as it requires a careful analysis of assumptions used.

GHG emission reduction cost

The model calculates the GHG emission reduction cost. The GHG emission reduction cost is calculated by dividing the annual life cycle savings (ALCS) of the project by the net GHG emission reduction per year. For projects with a net increase in GHG emission, the GHG emission reduction cost is irrelevant and hence not calculated.

Project equity

The model calculates the project equity, which is the portion of the total investment required to finance the project that is funded directly by the project owner(s). The project equity is deemed to be disbursed at the end of year 0, i.e. the development/construction year. It is calculated using the total initial costs, the initial cost incentives and the debt ratio.

Project debt

The model calculates the project debt, which is the portion of the total investment required to implement the project and that is financed by a loan. The project debt leads to the calculation of the debt payments and the net present value. It is calculated using the total initial costs and the project equity.

Debt payments

The model calculates the debt payments, which is the sum of the principal and interest paid yearly to service the debt. Whereas debt payments are constant over the debt term, the principal portion increases and the interest portion decreases with time. In that respect, it is similar to the yearly annuity paid to reimburse the mortgage of a house. Debt payments are calculated using the debt interest rate, the debt term and the project debt.

Debt service coverage

The model calculates the debt service coverage for each year of the project and reports the lowest ratio encountered throughout the term of debt. The debt service coverage is the ratio of the operating benefits of the project over the debt payments. This value reflects the capacity of the project to generate the cash liquidity required to meet the debt payments. It is calculated by dividing net operation income or savings (net cash flows before depreciation, debt payments and income taxes) by debt payments (principal and interest).

The debt service coverage is a ratio used extensively by the potential lenders for a project to judge its financial risk. The model assumes that the cumulative cash flows are used to finance a sufficient debt service reserve before any distributions to the shareholders.

Yearly Cash Flows

Pre-tax

The model calculates the net pre-tax cash flows, which are the yearly net flows of cash for the project before income tax. It represents the estimated sum of cash that will be paid or received each year during the entire life of the project. Note that the initial costs are assumed to occur at the end of year 0 and that year 1 is the first year of operation of the project. Annual costs and savings given in the *Financial Summary* worksheet, which reflect amounts valid for year zero, are thus escalated one year in order to determine the actual costs and savings incurred during the first year of operation (i.e. year 1).

After-tax

The model calculates the net after-tax cash flows, which are the yearly net flows of cash for the project after income tax. It represents the estimated sum of cash that will be paid or received each year during the entire life of the project. Note that the initial costs are assumed to occur at the end of year 0 and that year 1 is the first year of operation of the project. Annual costs and savings given in the *Financial Summary* worksheet, which reflect amounts valid for year zero, are thus escalated one year in order to determine the actual costs and savings incurred during the first year of operation (i.e. year 1).

Cumulative

The model calculates the cumulative cash flows, which represent the net after-tax flows accumulated from year 0. It uses the net flows to calculate the cumulative flows.

Cumulative Cash Flows Graph

The cumulative cash flows are plotted versus time in the cash flows graph. These cash flows over the project life are calculated in the model and reported in the Yearly Cash Flows table.

Blank Worksheets (3)

These worksheets are provided to allow the user to prepare a customised RETScreen project analysis. For example, the worksheets can be used to enter more details about the project, to prepare graphs, to perform a more detailed sensitivity analysis and to create a custom database. The user may also use these worksheets to develop a companion model to RETScreen.

Greenhouse Gas (GHG) Emission Reduction Analysis

As part of the RETScreen Clean Energy Project Analysis Software, a *GHG Analysis* worksheet is provided to help the user estimate the greenhouse gas emission reduction (mitigation) potential of the proposed project. This GHG emission reduction analysis worksheet contains four main sections: **Background Information, Base Case System (Baseline), Proposed Case System (Project)** and **GHG Emission Reduction Summary**. The Background Information section provides project reference information as well as GHG global warming potential factors. The Base Case Electricity System and the Base Case Heating System sections provide a description of the emission profile of the baseline system, representing the baseline for the analysis. The Proposed Case Heating System section provides a description of the emission profile of the proposed project, i.e. the solar air heating project. The GHG Emission Reduction Summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections and from values entered or calculated in the other RETScreen worksheets (e.g. annual energy delivered). Results are calculated as equivalent tonnes of CO_2 avoided per annum. This is an optional analysis - inputs entered in this worksheet will not affect results reported in other worksheets, except for the GHG related items that appear in the *Financial Summary* and *Sensitivity* worksheets.

Greenhouse gases include water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and several classes of halo carbons (that is, chemicals that contain carbon together with fluorine, chlorine and bromine). Greenhouse gases allow solar radiation to enter the Earth's atmosphere, but prevent the infrared radiation emitted by the Earth's surface from escaping. Instead, this outgoing radiation is absorbed by the greenhouse gases and then partially re-emitted as thermal radiation back to Earth, warming the surface. Greenhouse gases that are most relevant to energy project analysis are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); these gases are considered in the RETScreen GHG emission reduction analysis.

The *GHG Analysis* worksheet of each Workbook file has been developed with a common framework so as to simplify the task of the user in analysing the viability of different projects. Hence the description of each parameter is common for most of the items appearing in the worksheet. One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers.

The *GHG Analysis* worksheet with its emission related input items (e.g. fuel mix, fuel conversion efficiency) and its calculated emission factor output items (e.g. GHG emission factor), allows the decision-maker to consider various emission parameters with relative ease. However, the user should be aware that this ease of use may give a project developer a too optimistic and simplified view of what is required in setting a baseline for a proposed project. As such, it is suggested that the user **take a conservative approach in calculating the baseline emission factor for the project**, particularly at the pre-feasibility analysis stage. In order to determine the net benefits of obtaining carbon finance for the project, the user can evaluate the project twice, once including the value of the carbon credits and the associated transaction costs and once without, and then compare the results.

Use GHG analysis sheet?

The user indicates by selecting from the drop-down list whether or not the optional *GHG Analysis* worksheet is used to conduct an analysis of GHG emission reduction.

If the user selects "Yes" from the drop-down list, then the user should complete the *GHG Analysis* worksheet. Certain input fields will be added to the *Financial Summary* worksheet in order to calculate the GHG emission reduction income and cost.

If the user selects "No" from the drop-down list, then the user should go directly to the *Financial Summary* worksheet.

Type of analysis

The user selects the type of analysis from the two options in the drop-down list: "Standard" and "Custom." "Standard" analysis uses many pre-defined parameters in the calculations whereas "Custom" analysis requires that the user enter these parameters.

Background Information

Project name

The user-defined project name is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the GHG Analysis worksheet.

Project location

The user-defined project location is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the GHG Analysis worksheet.

Global Warming Potential of GHG

The model indicates the global warming potential of methane (CH_4) and nitrous oxide (N_2O). If the user selects the "Custom" type of analysis, different values from the default values provided may be entered by the user. Researchers have assigned Global Warming Potentials (GWPs) to greenhouse gases to allow for comparisons of their relative heat-trapping effect. The higher the global warming potential of a gas the greater the contribution to the greenhouse effect. For example nitrous oxide is 310 times more effective than carbon dioxide at trapping heat in the atmosphere.

GWPs of gases are defined as a unit multiple of that given to carbon dioxide (CO_2), which is assigned a reference value of 1 (i.e., the GWP of CO_2 is 1 and the GWP of N_2O is 310). The default values are those defined by the Revised Intergovernmental Panel on Climate Change (IPCC) Guidelines for Greenhouse Gas Inventories, 1996.

Base Case Electricity System (Baseline)

To perform the RETScreen GHG emission reduction analysis for the project, the user will need to define the baseline (also called base case or reference case) electricity system.

Note: Defining the Base Case Electricity System carefully is more important if the base case heating system fuel type, defined in the *Energy Model* worksheet, is electricity. Otherwise, this analysis applies only to the electricity used for the fan, which represents a relatively small amount of energy.

For example, in North America when preparing a GHG emission reduction analysis for a SAH project where central-grid electricity is used, it is often reasonable to assume that a combined-cycle natural gas power plant is the proxy plant. In this case the user need only select "Natural gas" as the fuel type with a 100% fuel mix and use the default "T & D losses" of 8%. For the case of an isolated-grid, a diesel genset would likely be the "proxy" power plant with "Diesel (#2 oil)" chosen as the fuel type.

It is also possible to define the grid and the mix of the different power plants with their respective fuels, fuel mix and different T & D losses (e.g. distributed generators such as photovoltaics will have lower T & D losses). This information is usually available through the local electric utility, the utility regulator and/or through government. For example, the United States Environmental Protection Agency (US-EPA) provides "The Emissions & Generation Resource Integrated Database" called E-GRID. This is a database featuring environmental characteristics of electric power generation in the US, including fuel mix. This database is available free of charge at the E-GRID Website.

To illustrate this alternative analysis method, for a solar air heating project based in Nova Scotia, Canada, the provincial government might determine the baseline to be the weighted average of the current generation mix. This can be calculated by simply entering the current fuel mix into the grid along with the appropriate emissions coefficient. For this example and with information provided by Natural Resources Canada, the user would select the following fuel types and associated fuel mix: coal with 78% of the fuel mix, large hydro with 9%, #6 oil with 5%, natural gas with 5% and biomass with 3% of the fuel mix and T & D losses of 8% for all fuel types.

Some users may prefer to perform a much more detailed analysis of the GHG reduction potential of the project (e.g. an economist working for a public utility commission). The model allows for a more detailed analysis regarding T & D losses and using the "Custom" option under the "Type of analysis" drop-down list, the user can prepare an even more detailed analysis regarding emission factors, etc.

If the user has access to dispatch information from the local utility, the Base Case Electricity System table can be used to model the marginal fuel use on the grid, which may more accurately represent the fuels and the emissions that are being displaced by the proposed project. For example, if dispatch information shows that the fuel used on the margin is natural gas 85% of the time and fuel oil 15% of the time, the user would enter these details into the base case table along

with the corresponding GHG coefficients. The resulting baseline is often referred to as the "operating margin."

Another baseline option, referred to as the "build margin" can be calculated by modeling recent capacity additions, for example, the 5 most recent plants that have been added to the grid. The build margin can be modeled in the base case table by entering recent capacity additions along with their relative generating capacities (scaled to total 100%) and appropriate GHG coefficients.

It is suggested that the user take a conservative approach in calculating the baseline emission factor for the project, particularly at the pre-feasibility analysis stage.

Fuel type

The user selects the fuel type from the options in the drop-down list. The RETScreen software can model the GHG emissions of any electricity supply system. The fuel type is the fuel(s) or power plant(s) which will be displaced by the proposed project. If the user selects one of the fuel types from the drop-down list, default emission factor and fuel conversion efficiency values will be inserted into the row inputs of the table. The default emission factors and conversion efficiencies of various fuel types are given in the table below [Fenhann, J., 1999], [Fenhann, J., 2000] and [The Danish Energy Agency, 1999].

For "Custom" projects, if a specific fuel type is not included in the drop-down list, the user may choose "Other" and manually enter values for the remainder of the row inputs. The order in which reference fuels or power plants are listed in this table is irrelevant.

Fuel type	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency %
Coal	94.6	0.0020	0.0030	35%
Natural gas	56.1	0.0030	0.0010	45%
Nuclear	0	0	0	-
Large hydro	0	0	0	-
#6 oil	77.4	0.0030	0.0020	30%
Diesel (#2 oil)	74.1	0.0020	0.0020	30%
Geothermal	0	0	0	-
Biomass (wood)	0	0.0320	0.0040	25%
Small hydro	0	0	0	-
Wind	0	0	0	-
Solar	0	0	0	-
Propane	63.1	0.0010	0.0010	45%

Default Emission Factors and Conversion Efficiencies

Fuel mix

The user enters the fuel mix (%) of the base case electricity system for each fuel type. Units are given as percentages of total electricity supplied. Note that the user should verify that the sum of all fuel types listed in the fuel mix column equals 100%.

CO_2, CH_4 and N_2O emission factors

(Custom analysis)

The user enters the CO_2, CH_4 and N_2O emission factors for the different fuel types. They represent the mass of greenhouse gas emitted per unit of energy. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. For grid-connected projects, the user should enter factors representative of large generating plants. On the electricity mix row at the bottom of the table, the model calculates the equivalent emission factors for the global electricity mix and per unit of electricity delivered. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T & D losses of the different fuel types.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ). For the global electricity mix shown on the bottom row of the table, units are given in kilograms of gas emitted per gigajoule of end-use electricity delivered.

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. CO_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

CO_2, CH_4 and N_2O emission factors

(Standard analysis)

The model provides the CO_2, CH_4 and N_2O emission factors which represent the mass of greenhouse gas emitted per unit of energy. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. The default factors provided are those which are representative of large power plants that feed a central electricity grid. On the electricity mix row at the bottom of the table, the model calculates the equivalent emission factors for the total electricity mix and per unit of electricity delivered. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T & D losses of the different fuel types.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ). For the total electricity mix shown on the bottom row of the table, units are given in kilograms of gas emitted per gigajoule of end-use electricity delivered.

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. CO_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

The default values provided by the model are given in Default Emission Factors and Conversion Efficiencies table.

Fuel conversion efficiency

(Custom analysis)

The user enters the fuel conversion efficiency for the selected fuel type. The fuel conversion efficiency is the efficiency of energy conversion from primary heat potential to actual power plant output. This value is used to calculate, for each fuel type, the aggregate GHG emission factor and therefore is only relevant for fuel types which actually produce greenhouse gases (i.e. with non-zero CO_2, CH_4 and N_2O emission factors).

For example, a typical coal-fired power plant could have a fuel conversion efficiency of 35%, which indicates that 35% of the heat content of the coal is transformed into electricity fed to the grid.

Units are given as a percentage of primary heat potential (gigajoules of heat) to actual power plant output (gigajoules of electricity). Fuel types which emit no GHGs (e.g., solar) have a default value of 100%.

Fuel conversion efficiency

(Standard analysis)

The model provides the fuel conversion efficiency for the selected fuel type. The fuel conversion efficiency is the efficiency of energy conversion from primary heat potential to actual power plant output. This value is used to calculate, for each fuel type, the aggregate GHG emission factor and therefore is only relevant for fuel types which actually produce greenhouse gases (i.e. with non-zero CO_2, CH_4 and N_2O emission factors).

For example, a typical coal-fired power plant could have a fuel conversion efficiency of 35%, which indicates that 35% of the heat content of the coal is transformed into electricity fed to the grid.

Units are given as a percentage of primary heat potential (gigajoules of heat) to actual power plant output (gigajoules of electricity). Fuel types which emit no GHGs (e.g., solar) have a default value of 100%.

The default values provided by the model are given in Default Emission Factors and Conversion Efficiencies table.

Transmission and distribution losses

The user enters the transmission and distribution (T & D) losses (%) of the base case electricity system, which includes all energy losses between the power plant and the end-user. This value will vary based on the voltage of transport lines, the distance from the site of energy production to the point of use, peak energy demands, ambient temperature and electricity theft. In addition, T & D system type (e.g. AC vs. DC) and quality may also influence losses. The model calculates the weighted average of the T & D losses of the global electricity mix on the bottom row of the table.

Units are given as a percentage of all electricity losses to electricity generated. It is reasonable to assume T & D losses of 8 to 10% in modern grids in industrialised countries and 10 to 20% in grids located in developing countries.

GHG emission factor

The model calculates the GHG emission factor for each reference fuel type. Values are calculated based on the individual emission factors, the fuel conversion efficiency and the T & D losses. The weighted GHG emission factor for the total electricity mix is calculated on the bottom row of the table.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use electricity delivered (t_{CO2} / MWh).

Base Case Heating System (Baseline)

The base case heating system, or reference system, represents the system to which the solar air heating system is compared. The base case heating system is defined in terms of its fuel types, its emissions of GHG and its conversion efficiencies.

The base case system is normally referred to as the reference or baseline option in standard economic analysis.

Fuel type

The fuel type of the base case heating system entered by the user in the *Energy Model* worksheet is copied automatically to the *GHG Analysis* worksheet.

Fuel mix

The base case heating system is assumed to be fuelled by a single source of energy and the fuel mix is therefore set to 100%.

CO_2, CH_4 and N_2O emission factors

(Custom analysis)

For the base case heating system, the user enters the CO_2, CH_4 and N_2O emission factors corresponding to the heating fuel type selected. If the heating fuel type is electricity, emission factors of the base case electricity mix are used.

CO_2, CH_4 and N_2O emission factors represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of heating equipment.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heating energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. CO_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

CO_2, CH_4 and N_2O emission factors

(Standard analysis)

For the base case heating system, the model provides the CO_2, CH_4 and N_2O emission factors corresponding to the heating fuel type selected. If the heating fuel type is electricity, emission factors of the base case electricity mix are used.

CO_2, CH_4 and N_2O emission factors represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of heating equipment. The default factors provided are those which are representative of large heating plants. For smaller plants and for greater accuracy, the user may select the "Custom" type of analysis and specify the emission factors.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of primary heating energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. CO_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

The default values provided by the model are given in Default Emission Factors and Conversion Efficiencies table.

Fuel conversion efficiency

The base case heating system fuel conversion efficiency is entered by the user in the *Energy Model* worksheet and is copied automatically to the *GHG Analysis* worksheet. The fuel conversion efficiency represents the annual average efficiency of energy conversion from primary heat potential to actual heating energy output. This value is used to calculate, for each fuel type, the aggregate GHG emission factor and therefore is only relevant for fuel types which actually produce greenhouse gases (i.e. with non-zero CO_2, CH_4 and N_2O emission factors).

Units are given as a percentage of actual heating energy output (gigajoules of heating energy) to primary heat potential (gigajoules of heat or electricity).

GHG emission factor

The model calculates the GHG emission factor for the base case heating system. Values are calculated based on the individual emission factors and the fuel conversion efficiency.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO2} / MWh).

Proposed Case Heating System (Solar Air Heating Project)

The proposed case heating system, or mitigation system, is the solar air heating system. It is defined in terms of its fuel types, its emissions of GHG and its conversion efficiencies. Note that in all cases, the fans, if any, of the solar air heating system are assumed to be electricity-driven using the base case electricity system.

The proposed case system is normally referred to as the mitigation option in standard economic analysis.

Fuel type

The fuel type of the solar air heating system is assumed to be solar with electricity to drive the fans.

Fuel mix

The fuel mix of the solar air heating system is assumed to come from a two sources, i.e. solar and electricity, totalling 100 %.

CO_2, CH_4 and N_2O emission factors

(Custom analysis)

The user enters the CO_2, CH_4 and N_2O emission factors corresponding to the solar energy provided by the solar air heating system. The model provides the electricity values corresponding to the electricity mix of the base case electricity system.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of primary heat used by the solar air heating system (kg/GJ).

CO_2, CH_4 and N_2O emission factors

(Standard analysis)

The model provides the CO_2, CH_4 and N_2O emission factors corresponding to the fuel type, i.e. solar and electricity for the solar air heating system. The electricity values correspond to the electricity mix of the base case electricity system.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of primary heat used by the solar air heating system (kg/GJ).

Fuel conversion efficiency

Fuel conversion efficiencies for both the solar energy and electricity are set to 100%.

This value is used in conjunction with the CO_2, CH_4 and N_2O emission factors to calculate the aggregate GHG emission factor for the solar air heating system.

Units are given as a percentage of actual heating energy output (gigajoules of heating energy) to primary energy input (gigajoules of heat).

GHG emission factor

The model calculates the GHG emission factor for the proposed project. Values are calculated based on the individual CO_2, CH_4 and N_2O emission factors and the fuel conversion efficiency.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO2} / MWh).

GHG Emission Reduction Summary

Based on the GHG emission data entered, the model calculates the annual reduction in GHG emissions when the base case system is displaced with the proposed case system.

Base case GHG emission factor

The model transfers the base case GHG emission factor calculated in the base case heating system (baseline) section. This value represents the amount of GHG emitted per unit of heating energy delivered for the base case system.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO2} / MWh).

Proposed case GHG emission factor

The model transfers the proposed case GHG emission factor calculated in the proposed case heating system section. This value represents the amount of GHG emitted per unit of heating energy delivered if the solar air heating system is installed.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO2} / MWh).

End-use annual energy delivered

The model displays the end-use annual energy delivered, as calculated in the *Energy Model* worksheet.

Units are given in megawatt-hours of end-use heating energy delivered (MWh).

Annual GHG emission reduction

The model calculates the annual reduction in GHG emissions estimated to occur if the proposed project is implemented. The calculation is based on emission factors of both the base case and the proposed case system and on the end-use annual energy delivered.

Units are given in equivalent tonnes of CO_2 emission per year (t_{CO2}/yr).

Note: At this point, the user should complete the *Financial Summary* worksheet.

Sensitivity and Risk Analysis

As part of the RETScreen Clean Energy Project Analysis Software, a *Sensitivity and Risk Analysis* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet contains two main sections: **Sensitivity Analysis** and **Risk Analysis**. Each section provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The Sensitivity Analysis section is intended for general use, while the Risk Analysis section, which performs a Monte Carlo simulation, is intended for users with knowledge of statistics.

Both types of analysis are optional. Inputs entered in this worksheet will not affect results in other worksheets.

Use sensitivity analysis sheet?

The user indicates, by selecting from the drop-down list, whether or not the optional *Sensitivity and Risk Analysis* worksheet is used to conduct a sensitivity analysis of the important financial indicators.

If the user selects "Yes" from the drop-down list, the sensitivity analysis section will open and the user should complete the top part of the worksheet. The user will need to click on "Calculate Sensitivity Analysis" button to get the results.

Perform risk analysis too?

The user indicates, by selecting from the drop-down list, whether or not the optional risk analysis section is used to conduct a risk analysis of the important financial indicators, in addition to the sensitivity analysis. In the risk analysis section, the impact of each input parameter on a financial indicator is obtained by applying a standardised multiple linear regression on the financial indicator.

If the user selects "Yes" from the drop-down list, then the risk analysis section will open and the user should complete the lower-half of the worksheet. The analysis will be performed on the financial indicator selected by the user in the "Perform analysis on" input cell at the top-right. The user will need to click on "Calculate Risk Analysis" button in the Risk Analysis section at the lower-half of this worksheet to get the results.

Project name

The user-defined project name is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Sensitivity* worksheet.

Project location

The user-defined project location is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Sensitivity* worksheet.

Perform analysis on

The user selects, from three options in the drop-down list, the financial indicator to be used for both the sensitivity and risk analyses. Modifying the selection in this cell will change the results in the worksheet.

Sensitivity range

The user enters the sensitivity range (%), which defines the maximum percentage variation that will be applied to all the key parameters in the sensitivity analysis results tables. Each parameter is varied by the following fraction of the sensitivity range : -1, -1/2, 0, 1/2, 1. This value is used in the sensitivity analysis section only.

The sensitivity range entered by the user must be a percentage value between 0 and 50%.

Threshold

The user enters the threshold value for the financial indicator selected. The threshold is the value under which (for the "After tax IRR and ROI" and "Net Present Value - NPV") or over which (for "Year-to-positive cash flow") the user considers that the proposed project is not financially viable. Results which indicate an unviable project, as defined by the user threshold, will appear as orange cells in the sensitivity analysis results tables. This value is used in the sensitivity analysis section only.

Click here to Calculate Sensitivity Analysis

The "Click here to Calculate Sensitivity Analysis" button updates the sensitivity analysis calculations using the input parameters specified by the user (i.e. "Perform analysis on" and "Sensitivity range" input cells). The sensitivity analysis tables are updated each time the user clicks on this button.

The sensitivity analysis calculations can take up to 15 seconds to run depending on the Excel version and the speed of the computer. When the sensitivity analysis is updated, the button disappears.

If the user makes any changes to the input parameters, or navigates through any of the other worksheets, the button will reappear. The user will then have to click on the button to update the sensitivity analysis calculations so that the results reflect the changes.

Sensitivity Analysis for ...

This section presents the results of the sensitivity analysis. Each table shows what happens to the selected financial indicator (e.g. After-tax IRR and ROI) when two key parameters (e.g. Initial costs and Avoided cost of heating energy) are varied by the indicated percentages. Parameters are varied using the following fraction of the sensitivity range: -1, -1/2, 0, 1/2, 1. Original values (which appear in the *Financial Summary* worksheet) are in bold in these sensitivity analysis results tables.

Results which indicate an unviable project, as defined by the user threshold, will appear as orange cells in these sensitivity analysis results tables.

All parameter values used for the calculations are taken from the *Financial Summary* worksheet and all the sensitivity variations are evaluated at the level of that worksheet. This is a partial limitation of this sensitivity analysis worksheet since some parameter values are calculated from inputs in other worksheets, but those inputs are not changed. However, for most cases, this limitation is without consequence. If required, the user can use the blank worksheets (Sheet1, etc.) to perform a more detailed analysis.

Risk Analysis for ...

This section allows the user to perform a Risk Analysis by specifying the uncertainty associated with a number of key input parameters and to evaluate the impact of this uncertainty on after-tax IRR and ROI, year-to-positive cash flow or net present value (NPV).

The risk analysis is performed using a Monte Carlo simulation that includes 500 possible combinations of input variables resulting in 500 values of after-tax IRR and ROI, year-to-positive cash flow or net present value (NPV). The risk analysis allows the user to assess if the variability of the financial indicator is acceptable, or not, by looking at the distribution of the possible outcomes. An unacceptable variability will be an indication of a need to put more effort into reducing the uncertainty associated with the input parameters that were identified as having the greatest impact on the financial indicator.

Avoided cost of heating energy

The avoided cost of heating energy is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the avoided cost of energy range. The range is a percentage corresponding to the uncertainty associated with the estimated avoided cost of heating energy value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the avoided cost of heating energy could take.

For example, a range of 10% for an avoided cost of heating energy of 0.09 $/kWh means that the avoided cost of heating energy could take any value between 0.081 and 0.099 $/kWh. Since 0.09

$/kWh is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the avoided cost of heating energy is known exactly by the user (no uncertainty), the user should enter a range of 0%.

Renewable energy delivered

The RE delivered is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the energy delivered range. The range is a percentage corresponding to the uncertainty associated with the estimated energy delivered value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the energy delivered could take.

For example, a range of 10% for a energy delivered of 400 MWh means that the energy delivered could take any value between 360 and 440 MWh. Since 400 MWh is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the energy delivered is known exactly by the user (no uncertainty), the user should enter a range of 0%.

Initial costs

The total initial cost is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the initial costs range. The range is a percentage corresponding to the uncertainty associated with the estimated initial costs value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the initial costs could take.

For example, a range of 10% for initial costs of $30,000 means that the initial costs could take any value between $27,000 and $33,000. Since $30,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the initial costs are known exactly by the user (no uncertainty), the user should enter a range of 0%.

Annual costs

The annual cost is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet, but does not include debt payments.

The user enters the annual cost range. The range is a percentage corresponding to the uncertainty associated with the estimated annual costs value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the annual costs could take.

For example, a range of 10% for an annual cost of $800 means that the annual cost could take any value between $720 and $880. Since $800 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the annual costs are known exactly by the user (no uncertainty), the user should enter a range of 0%.

Debt ratio

The debt ratio is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt ratio range. The range is a percentage corresponding to the uncertainty associated with the estimated debt ratio value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0% and the lowest percentage such that the debt ratio will always fall between 0 and 100%. The range determines the limits of the interval of possible values that the debt ratio could take.

For example, a range of 10% for a debt ratio of 70% means that the debt ratio could take any value between 63 and 77%. Since 70% is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt ratio is known exactly by the user (no uncertainty), the user should enter a range of 0%.

Debt interest rate

The debt interest rate is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt interest rate range. The range is a percentage corresponding to the uncertainty associated with the estimated debt interest rate value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the debt interest rate could take.

For example, a range of 10% for a debt interest rate of 20% means that the debt interest rate could take any value between 18 and 22%. Since 20% is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt interest rate is known exactly by the user (no uncertainty), the user should enter a range of 0%.

Debt term

The debt term is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt term range. The range is a percentage corresponding to the uncertainty associated with the estimated debt term value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0% and the lowest percentage such that the debt term will always fall between 1 year and the project life. The range determines the limits of the interval of possible values that the debt term could take.

For example, a range of 10% for a debt term of 20 years means that the debt term could take any value between 18 and 22 years. Since 20 years is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt term is known exactly by the user (no uncertainty), the user should enter a range of 0%.

GHG emission reduction credit

The GHG emission reduction credit is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the GHG emission reduction credit range. The range is a percentage corresponding to the uncertainty associated with the estimated GHG emission reduction credit value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0 and 50%. The range determines the limits of the interval of possible values that the GHG emission reduction credit could take.

For example, a range of 10% for a GHG emission reduction credit of $\$5/t_{CO2}$ means that the GHG emission reduction credit could take any value between 4.5 and $\$5.5/t_{CO2}$. Since $\$5/t_{CO2}$ is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the GHG emission reduction credit is known exactly by the user (no uncertainty), the user should enter a range of 0%.

Click here to Calculate Risk Analysis

The "Click here to Calculate Risk Analysis" button updates the risk analysis calculations using the input parameter ranges specified by the user. Clicking on this button starts a Monte Carlo simulation that uses 500 possible combinations of input variables resulting in 500 values of the selected financial indicator. The impact graph, the median, the minimum and maximum confidence levels, and the distribution graph are calculated using these results and updated each time the user clicks on the button "Click here to Calculate Risk Analysis."

The risk analysis calculations can take up to 1 minute to run depending on the Excel version and the speed of the computer. When the risk analysis is updated, the button disappears.

If the user makes any changes to the input range values, or navigates through any of the other worksheets, the button will reappear. The user will then have to click on the button to update the risk analysis calculations so that the results reflect the changes.

Impact graph

The impact graph shows the relative contribution of the uncertainty in each key parameter to the variability of the financial indicator. The X axis at the bottom of the graph does not have any units, but rather presents a relative indication of the strength of the contribution of each parameter.

The longer the horizontal bar, for a given input parameter, the greater is the impact of the input parameter on the variability of the financial indicator.

The input parameters are automatically sorted by their impact on the financial indicator. The input parameter at the top (Y axis) contributes the most to the variability of the financial indicator while the input parameter at the bottom contributes the least. This "tornado graph" will help the user determine which input parameters should be considered for a more detailed analysis, if that is required.

The direction of the horizontal bar (positive or negative) provides an indication of the relationship between the input parameter and the financial indicator. There is a positive relationship between an input parameter and the financial indicator when an increase in the value of that parameter results in an increase in the value of the financial indicator. For example, there is usually a negative relationship between initial costs and the net present value (NPV), since decreasing the initial costs will increase the NPV.

In some cases, there is insufficient data to properly plot the graph. For example, when the year-to-positive cash flow is immediate, the result is not a numerical value, and therefore these values cannot be plotted.

Median

The model calculates the median of the financial indicator. The median of the financial indicator is the 50th percentile of the 500 values generated by the Monte Carlo simulation. The median will normally be close to the financial indicator value calculated in the *Financial Summary* worksheet.

Level of risk

The user selects from the drop-down list the acceptable level of risk for the financial indicator under consideration. The options are: 5%, 10%, 15%, 20% and 25%.

The level of risk input is used to establish a confidence interval (defined by maximum and minimum limits) within which the financial indicator is expected to fall. The level of risk represents the probability that the financial indicator will fall outside this confidence interval.

The limits of the confidence interval are automatically calculated based on the median and the level of risk, and are shown as "Minimum within level of confidence" and "Maximum within level of confidence."

It is suggested that the user select a level of risk of 5 or 10%, which are typical values for standard risk analysis.

Minimum within level of confidence

The model calculates the "Minimum within level of confidence," which is the lower limit of the confidence interval within which the financial indicator likely falls. It is the percentile of the distribution of the financial indicator corresponding to half the level of risk defined by the user. For example, for a "Minimum within level of confidence" value of 15% IRR, a level of risk of 10% means that 5% (half the level of risk) of the possible IRR values are lower than 15%.

Maximum within level of confidence

The model calculates the "Maximum within level of confidence," which is the upper limit of the confidence interval within which the financial indicator likely falls. It is the percentile of the distribution of the financial indicator corresponding to 100% minus half the level of risk. For example, for a "Maximum within level of confidence" value of 25% IRR, a level of risk of 10% means that 95% of the possible IRR values are lower than 25%.

Distribution graph

This histogram provides a distribution of the possible values for the financial indicator resulting from the Monte Carlo simulation. The height of each bar represents the frequency (%) of values that fall in the range defined by the width of each bar. The value corresponding to the middle of each range is plotted on the X axis.

Looking at the distribution of financial indicator, the user is able to rapidly assess its' variability.

In some cases, there is insufficient data to properly plot the graph. For example, when the year-to-positive cash flow is immediate, the result is not a numerical value, and therefore these values cannot be plotted.

Bar graph

The bar graph summarises the maximum and minimum financial indicator values that can be expected according to the level of risk defined by the user.

Product Data

Some of the product data requirements for the model are provided in the RETScreen Online Product Database. To access the product database the user may refer to "Data & Help Access." The product database provides information on the equipment associated with the project. From the Online Product Database dialogue box the user may obtain product specification and performance data, as well as company contact information.

From the dialogue box the user selects the Region, followed by the Supplier and Colour. The data can be pasted from the dialogue box to the spreadsheets by clicking on the "Paste Data" button. Only data that are in **bold** are pasted to the spreadsheets; all other data are provided for reference purposes only. Data entered using the product database may be **overwritten**; i.e. the user may prefer to use other data and can manually enter values into the spreadsheets. "Other information" such as product weight and/or dimensions, is provided to help the user prepare the study. The product database contains a link to the Websites of some product suppliers. In the case where the Website link cannot be activated the user should try using another browser or can contact the supplier by other means (email, fax, etc.).

Note: To see all the suppliers listed in the product database and their contact information, the user can choose "Any" from the "Region" input cell.

The product database is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada nor its ministers, officers, employees or agents make any warranty in respect to this database or assumes any liability arising out of this database.

Product manufacturers interested in having their products listed in the product database can reach RETScreen® International at:

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CANMET Energy Technology Centre - Varennes
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Tel: +1-450-652-4621
Fax: +1-450-652-5177
E-mail: rets-pdb@nrcan.gc.ca

Weather Data

This database includes some of the weather data required in the model. To access the weather database the user may refer to "Data & Help Access." While running the software the user may obtain weather data from **ground monitoring stations** and/or from **NASA's satellite data** and/or from other data sources such as the **Solar and Wind Energy Resource Assessment (SWERA)**. Ground monitoring stations data is obtained by making a selection for a specific location from the online weather database dialogue box. NASA's satellite data is obtained via a link to NASA's Website from the dialogue box.

Ground Monitoring Stations Data

From the dialogue box, the user selects a region, then a country, then a sub-region (provinces in Canada, states in the United States and N/A in the rest of the countries), and finally a weather station location. The weather station usually corresponds to the name of a city/town within the selected country. From the dialogue box the data can be pasted to the spreadsheets by clicking on the "Paste Data" button. Only data that are in **bold** are pasted to the spreadsheets; all other data are provided for reference purposes only. Data entered using the online weather database may be **overwritten**; i.e. the user may prefer to use other data and can manually enter values into the spreadsheets. As an alternative the user can use the NASA satellite data, particularly for the case when the project location is not close to the given weather station location.

NASA Global Satellite Data

A link to the NASA Surface meteorology and Solar Energy Data Set Website is provided in the online weather database dialogue box. The user is able to select the data required for the model by clicking on a region on the world map illustrated on the NASA Website. The location is narrowed down to a "cell" within a specified latitude and longitude. The user may simply copy and paste this data to the RETScreen spreadsheets or manually enter these values.

NASA and CETC - Varennes are co-operating to facilitate the use of NASA's global satellite solar data with RETScreen and to develop a new global weather database (see Surface meteorology and Solar Energy Data Set for the tool). This work is sponsored as part of NASA's Earth Science Enterprise Program and is being carried out at the NASA Langley Research Center and at CETC - Varennes. This collaboration provides RETScreen users access (free-of-charge) to satellite data (e.g. the amount of solar energy striking the surface of the earth, global temperatures and wind speeds), simply by clicking on links in either the RETScreen software or the NASA Website. These data had previously only been available from a limited number of ground monitoring stations and are critical for assessing the amount of energy a project is expected to produce. The use of these data results in substantial cost savings for users and increased market opportunities for industry while allowing governments and industry to evaluate regional renewable energy resource potential.

Cost Data

Typical cost data required to prepare RETScreen studies are provided in the RETScreen Online Cost Database and in the Online Manual. This database is built into the "right-hand column" of the *Cost Analysis* worksheet. Data are provided for Canadian costs with 2004 as a baseline year. The user also has the ability to create a custom cost database.

The user selects the reference (from the *Cost Analysis* worksheet) that will be used as a guideline for the estimation of costs associated with the implementation of the project. This feature allows the user to change the "Quantity Range" and the "Unit Cost Range" columns. The options from the drop-down list are: "Canada - 2004," "None," "Second currency" and a selection of 8 user-defined options ("Enter new 1," "Enter new 2," etc.).

If the user selects "Canada - 2004" the range of values reported in the "Quantity Range" and "Unit Cost Range" columns are for a 2004 baseline year, for projects in Canada and in Canadian dollars.

Selecting "None" hides the information presented in the "Quantity Range" and "Unit Cost Range" columns. The user may choose this option, for example, to minimise the amount of information printed in the final report.

If the user selects "Second currency" two additional input cells appear in the next row: "Second currency" and "Rate: 1st currency / 2nd currency." In addition, the "Quantity Range" and "Unit Cost Range" columns change to "% Foreign" and "Foreign Amount," respectively. This option allows the user to assign a portion of a project cost item in a second currency, to account for those costs that must be paid for in a currency other than the currency in which the project costs are reported. Note that this selection is for reference purposes only, and does not affect the calculations made in other worksheets.

If "Enter new 1" (or any of the other 8 selections) is selected, the user may manually enter quantity and cost information that is specific to the region in which the project is located and/or for a different cost base year. This selection thus allows the user to customise the information in the "Quantity Range" and "Unit Cost Range" columns. The user can also overwrite "Enter new 1" to enter a specific name (e.g. Japan - 2001) for a new set of unit cost and quantity ranges. The user may also evaluate a single project using different quantity and cost ranges; selecting a new range reference ("Enter new 1" to "Enter new 8") enables the user to keep track of different cost scenarios. Hence the user may retain a record of up to 8 different quantity and cost ranges that can be used in future RETScreen analyses and thus create a localised cost database.

Training and Support

The user can obtain current information on RETScreen Training & Support at the following Website address: www.retscreen.net/e/training.

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